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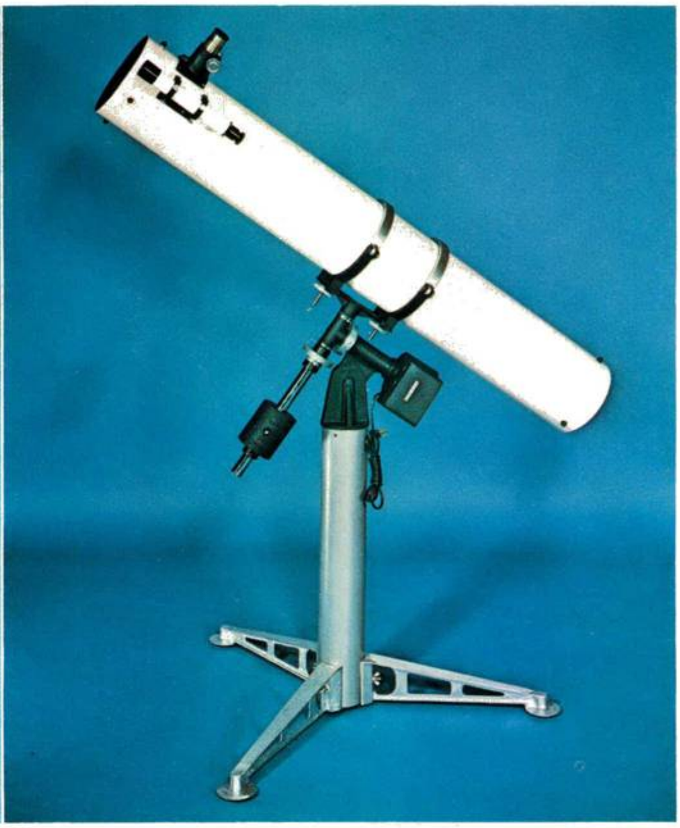

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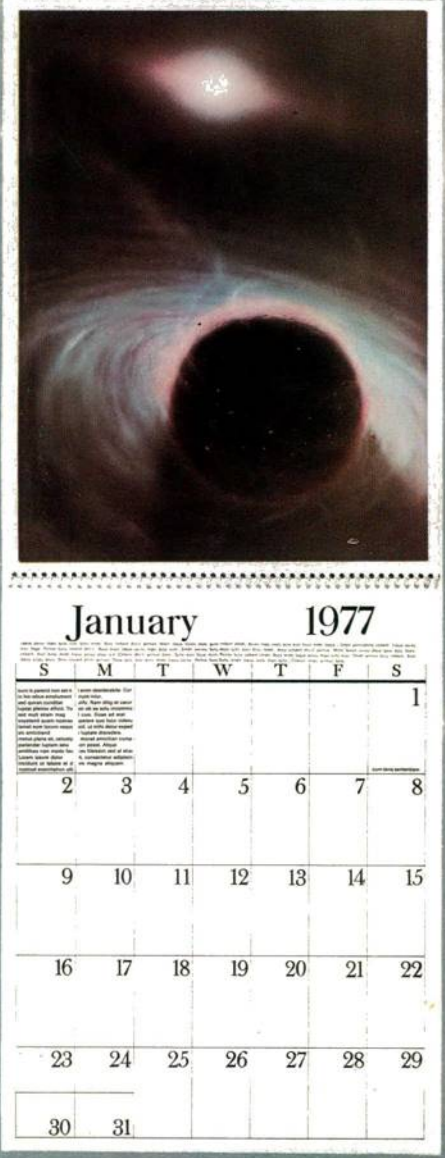

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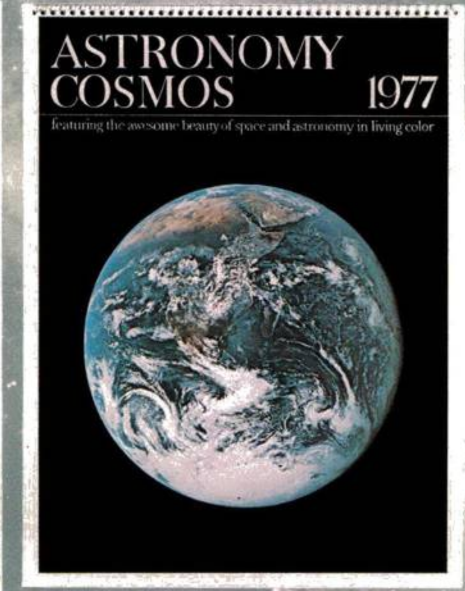

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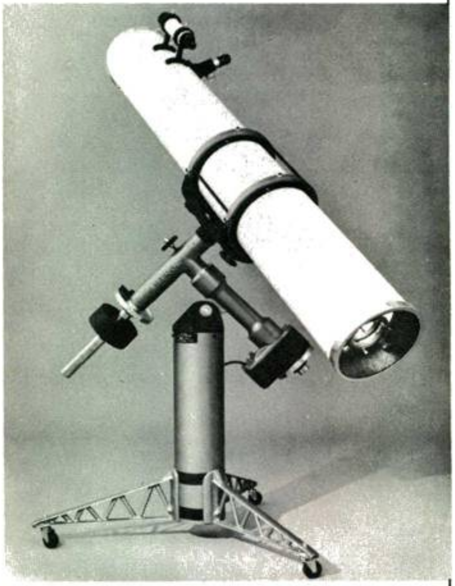

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Cover

A total eclipse of the sun moved across a wide track of Australia on Oct. 23, 1976, but most observers saw it through clouds. On this month's cover, smoke-like cirrus clouds scatter some of the light from the solar corona at midtotality into a soft halo of mixed corona and cloudlight. The poles of the sun, tipped some 26 degrees counterclockwise in the photograph, show brushy little spikes in the corona. This month, ASTRONOMY brings you the latest information about the tiny moons of Mars and the globe-grinding Martian duststorms. Looking deep into space, we also present some brand new color pictures of the galaxies from Kitt Peak's IPPS machine — a fantastic blend of photography, telescope and computer technology. If you're new to observing, Gazer's Gazette tells you what to look for if you live in the city, and Equipment Atlas answers your questions about binoculars. Photograph by Wendy Carlos.

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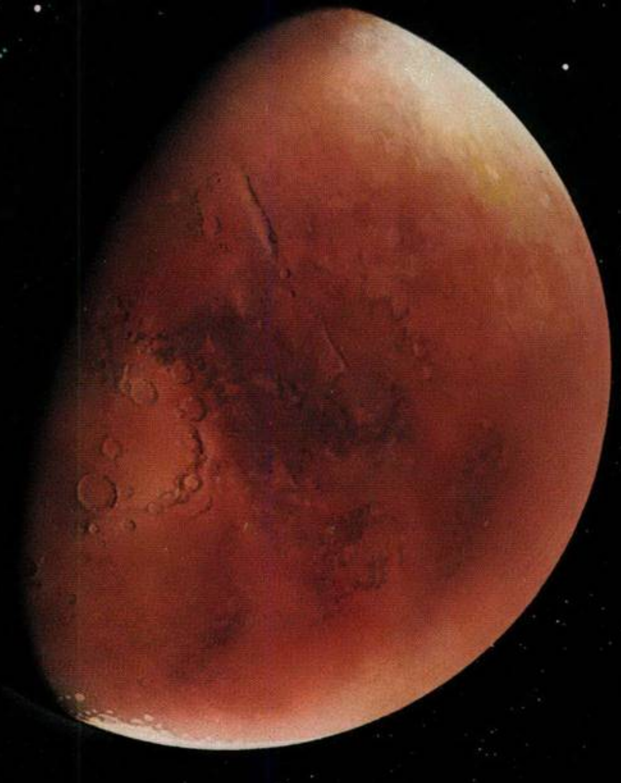
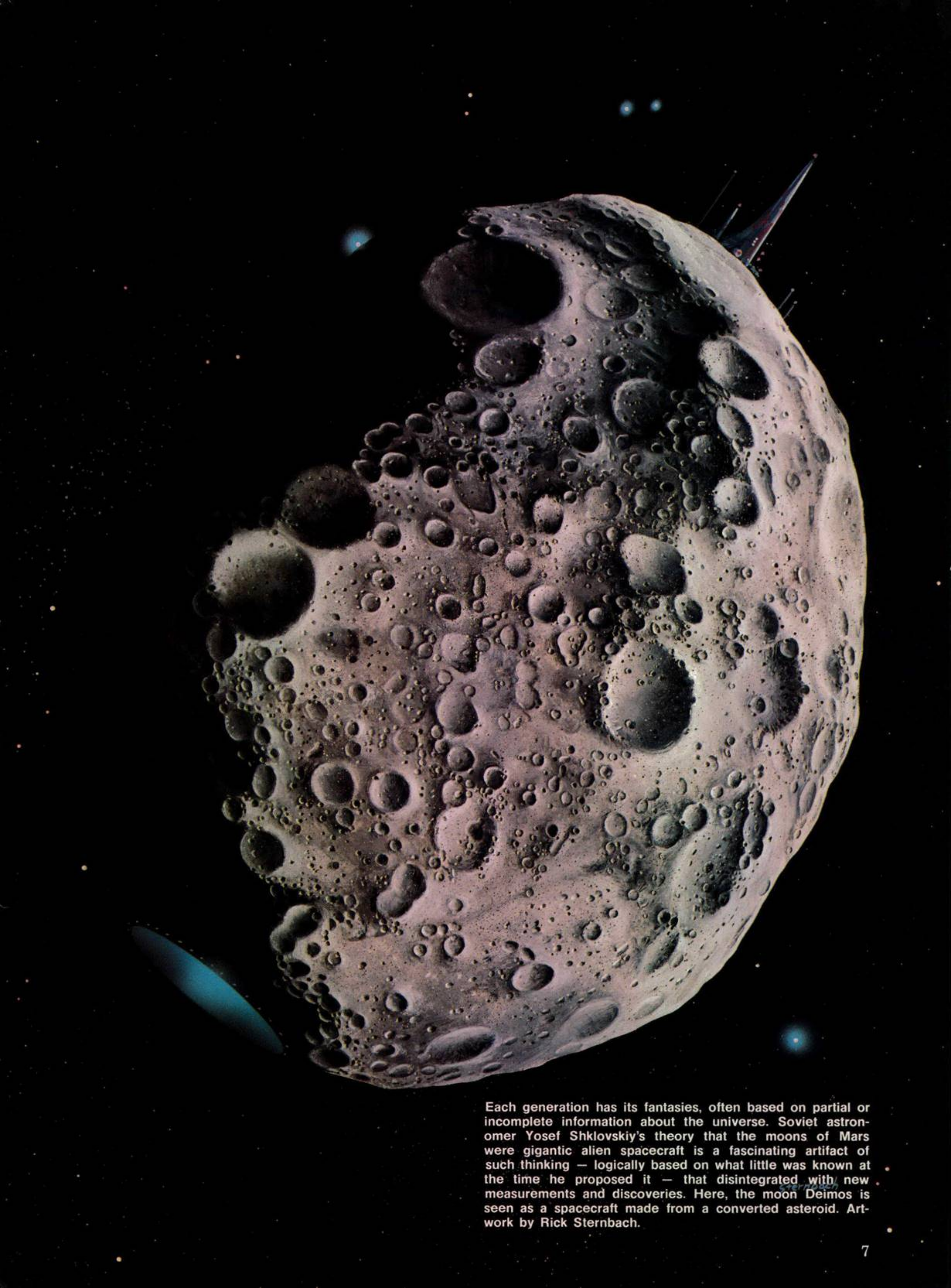
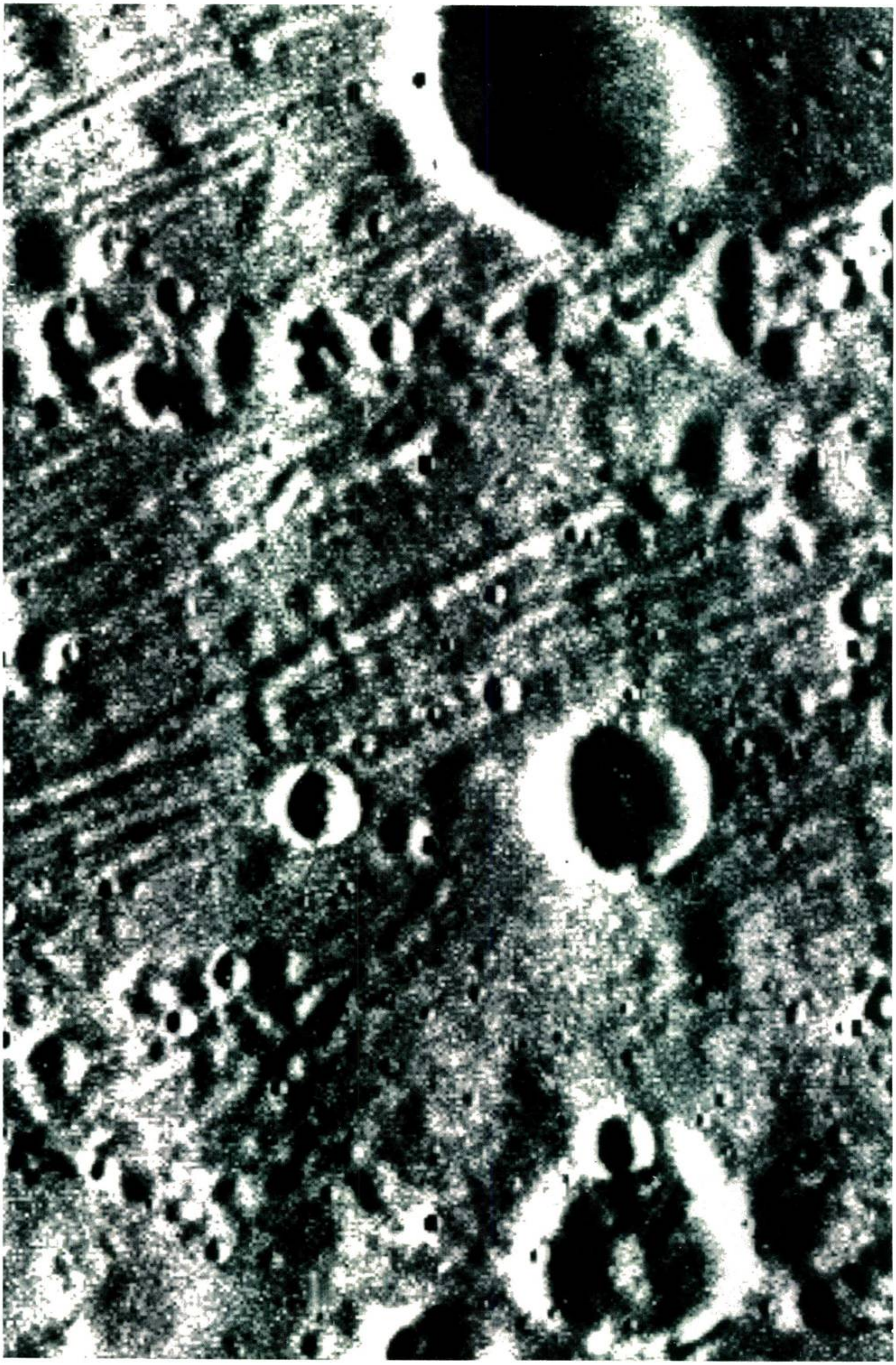
PHOBOS AND DEIMOS

by
James Oberg





Each generation has its fantasies, often based on partial or incomplete information about the universe. Soviet astronomer Yosef Shklovskiy's theory that the moons of Mars were gigantic alien spacecraft is a fascinating artifact of such thinking — logically based on what little was known at the time he proposed it — that disintegrated with new measurements and discoveries. Here, the moon Deimos is seen as a spacecraft made from a converted asteroid. Artwork by Rick Sternbach.



The view from Utopia is almost a Martian still life painting. Through the eyes of Viking 2, the only things that move are the shadows and wisps of high altitude clouds. The Viking cameras were designed with that expectation — they take many minutes to assemble one image — and would probably not even see something walking by (the seismometer, however, would probably hear it!).

But two objects do move, and Viking 2 will be turning its eyes to look for them during the Viking extended mission (which began earlier this year). On the southwestern horizon a dark oval smudge perhaps half the visual diameter of Earth's moon from Earth will pop up behind a hill, its odd shape made even more bizarre by the weak atmospheric refraction effects of Mars' thin air. The object will rise in a shallow arc toward the south, taking about 1-1/2 hours to reach a maximum elevation of about 20 degrees above the horizon. During the next 1-1/2 hours it will sink back toward the southeastern horizon and vanish. Farther to the east, a smaller object will jump from the horizon at a steeper angle, crossing the sky in a westerly direction and climbing halfway to the zenith a day after it first appears. Then it returns toward the west on a slow course, taking another full day and night to set and go through its phases twice, while the southerly object appears and reappears several times in its opposite flight path.

Viking is not being reconnoitered by Martians; it is watching the motions of Phobos and Deimos, the two small "moonlets" of Mars. Scientists are looking more and more closely at these two misshapen hunks of cosmic rubble, because there are many more puzzles to them than merely their shapes and flight paths. They have already revealed several crucial and unexpected bits of data that may be useful clues to the formation of the solar system. And they promise much more.

The view of Phobos and Deimos from the surface of Mars is one indication of how strange these two objects really are. Phobos, the inner moon, is so close to Mars that it circles the planet in less than one Martian day. Consequently it overtakes points on the planet's surface and appears to rise in the west. Since it is so close to Mars, observers in the higher latitudes may lose sight of it over the planet's equatorial curve. Any station much farther north than Viking 2 (about 48 degrees north) would never see Phobos at all.

Even for those within line of sight of Phobos, the seeing is not always believable. Since it is so close to the planet, most of its overhead passes at night are also "Phobos lunar eclipses" during which the moon is in the shadow of Mars. Its daytime passes are of course illuminated, but its sunlit side shows only as a crescent against the background brightness of the salmon pink Martian sky. The dark side is plainly illuminated by light reflected off Mars to Phobos and back to Mars again. Despite the much lower reflectivity of Mars and Phobos compared to Earth, the much shorter orbital radius of the moonlet allows the "Marslight" to be several thousand times brighter than the dim "Earthlight" that often fills out the disk of a new moon seen from Earth.

The best photograph of the surface of Phobos was taken in September 1976 by Viking Orbiter 2 from a distance of 545 miles (880 kilometers). Craters are evident, as well as crater chains, and Phobos' surprising striations. During March 1977, still closer flybys by the Viking craft are expected to show much finer detail, revealing features only a few feet across. In this photograph, the individual picture elements (pixels) that make up the image can be seen. NASA photograph.

Phobos and Deimos were first seen by astronomers 100 years ago, but they had been "invented" by astrologers centuries before. The fact that writers in the 18th century discussed the "two moons of Mars" in uncanny detail has led to boundless speculation of secret space travelers, psychic powers, and close encounters between Earth and Mars within recorded time. The actual explanation seems to involve a combination of entirely fallacious reasoning and basic celestial mechanics.

Johannes Kepler, known to today's scientists as one of the founders of modern astronomy, actually made his living casting horoscopes for the European nobility. Numerology was very popular in the Middle Ages, and many scientists were dedicating their efforts to discovering the hidden harmony of the universe (the "music of the spheres"), hoping to show that the universe had a purposeful and logical creation. Since it appeared that Mercury and Venus had no moons, Earth had one, and Jupiter had four, the logical progression of numbers called for Mars to have two moons. Since astronomers of the 17th century had not yet seen them, they presumed them to be very small (which the numerologists considered sort of a sneaky way to show the symmetry of the planets) or close enough to the planet that they would be drowned out in the glare of reflected sunlight.

The English writer Jonathan Swift was probably only repeating some astrologer's speculation when, in 1726, he included a passage in **Gulliver's Travels** describing the Martian moons. That passage has been teasing and tantalizing observers ever since, as they seek deep hidden meanings in the esoteric knowledge that Swift displayed. He cited a group of astronomers:

"They have likewise discovered two lesser stars, or 'satellites', which revolve about Mars, whereof the innermost is distant from the center of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half."

The periods of the satellites are related to the orbital radii by Kepler's square-cube law, with which English astrologers and astronomers were quite familiar. Although at first glance the figures reported by Swift are remarkably close to reality, they are not that good. Phobos is distant from Mars by only 1-1/2 diameters, and Deimos by 3-1/2. Their periods are about 8 hours and 30 hours. The constants of proportionality, in units of hours and Mars radii, are about 1/2 for Swift's guess and almost 3 for the actual values, which better than anything indicates that neither Swift nor anyone else really had any authentic knowledge of Phobos and Deimos.

A combination of events made 1877 the best opportunity ever for a Martian satellite search. It was one of the closest oppositions of Mars in decades — so close that in Europe, an Italian astronomer was for the first time able to make out "canali" on the Martian surface. At almost the same time, American astronomer Asaph Hall was searching near the bright Martian disk for signs of natural satellites. Using the new 26 inch refractor at the United States Naval Observatory in Washington, D.C. (which was superior in several respects to all previous instruments), Hall was evidently confident that he could find objects that had been impossible to detect with any other telescope.

But after almost giving up the search (he was encouraged to try one more night by his wife, Angelina Stickney Hall, who was rewarded a century later when the largest crater on Phobos was named Stickney), Hall finally succeeded in detecting two faint lights barely discernable in the glare near Mars. Phobos' movement was so unexpectedly rapid that when he saw it again the following night on the opposite side of Mars, he at first imagined that he had found a third satellite.

The companions of the god of war, in classical mythology, were Fear and Terror. In Greek mythology the chariot horses of Ares (Mars) were named Phobos and Deimos. Hall exercised the right of the discoverer and assigned these two appropriately belligerent names to the moonlets. If real fear and terror were as small and hard to find as their astronomical namesakes, perhaps he reasoned, the world would be a far more pleasant place.

For 70 years after their discovery, Deimos and Phobos remained only as footnotes in astronomy textbooks and minor solar system curiosities. Although they were the smallest satellites known, everyone quite logically assumed that the outer planets likely had dozens of similar tiny moonlets, which because of their distance were probably forever beyond the detection capabilities of Earth based telescopes.

The first odd and abnormal feature of Phobos was noticed in 1947, when American astronomer Stuart Sharpless attempted to reduce all of the past observations of the positions of Mars' moons into a single equation. After months of work, he found that Phobos did not fit simple laws of motion. Ever so slightly, Phobos was pulling ahead of its calculated position, and Sharpless did not understand why.

The rate of this "secular acceleration" was not spectacular. Over a half century, Phobos had built up a lead of about 15 minutes over where classical celestial mechanics theory said it should have been. This amounted o a two degree advance in its orbit around Mars. Something was retarding the forward motion of the satellite, causing it to fall into a slightly lower orbit. By the precise laws of celestial mechanics, the lower orbit was a faster one, and Phobos began to pull ahead of its predicted trajectory. Thus the retardation of its motion ultimately caused it to speed up!

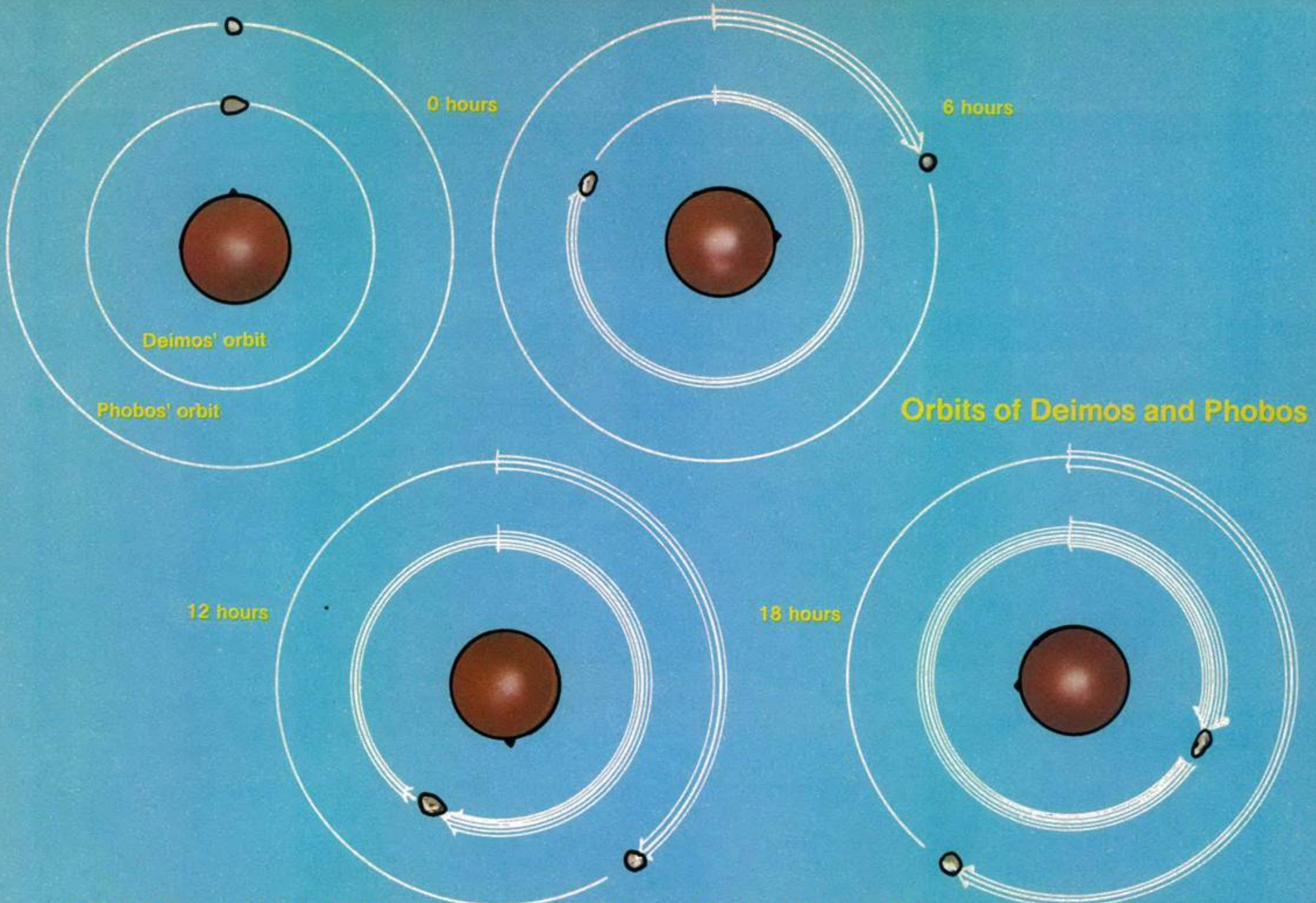
Other astronomers recomputed the acceleration. One set of calculations indicated that the anomaly was entirely due to random arithmetic errors, while different specialists in the U.S. and the Soviet Union confirmed that although an acceleration did exist, it was probably only half as great as Sharpless had originally suggested.

Several theories were proposed to account for the anomalous behavior of Phobos. The satellite might be retarded by the thin Martian atmosphere, or by interplanetary dust, or by the effects of light pressure (due to the Poynting-Robertson effect). Electromagnetic forces were suggested. Interactions between Phobos and the equatorial bulge of Mars, or with a fluid Martian core, might also lead to the acceleration through "tidal" forces which are much more evident in the Earth-moon system. A hit by a small meteor could have knocked Phobos off schedule, although this was unlikely since the acceleration was not sudden, but cumulative over the decades.

Using what was known about Mars and its satellites in the late 1950s, Soviet astronomer Yosef Shklovskiy eliminated all of the proposed theories as impossible. He then went back to some original assumptions which had never been questioned. In particular, Shklovskiy noticed that all calculations of air drag had presupposed that Phobos was of "ordinary" density — perhaps three to four times as heavy as water.

Working backward from the known drag and postulated size of Phobos, Shklovskiy computed the required density of Phobos if the retardation were due entirely to air drag. The answer was about 1,000 times less than that of water. No known material is that light, so Shklovskiy theorized that Phobos was hollow. The logic flowed on faultlessly: If Phobos were hollow, it was hard to imagine it as a natural object. If it were an artificial object, it would have been many miles across. Space planners have only recently even begun to imagine such sized structures for the L-5 space colonies of the 21st century.

The sensational news that Phobos might be artificial made a tremendous impact on the imagination of the general public. Scientists remained suspicious because Shklovskiy's theory was a negative one; it was the result of the elimination of all other possibilities. Such a technique of proof is a very



Orbits of Deimos and Phobos

Imagine a mountain on Mars lined up to start a race with Deimos and Phobos at 0 hours. Phobos is way out front 6 hours later having completed 80 percent of an orbit; Mars has turned about 1/4 turn, and Deimos has made a leisurely 1/5 revolution. At 12 hours, Phobos is already halfway around its next orbit, while Mars and Deimos trail behind. At the end of 18 hours, with Phobos already well into its third orbit, Mars has finished 3/4 turn, and Deimos a bit over 1/2 its orbit.

risky one in a field such as planetary astronomy, because new facts and new possibilities are always coming to light. Shklovskiy's ideas, proposed simply as one hypothesis, prompted other scientists to seek those new possibilities.

When Mariner 9 arrived at Mars in 1971, a worldwide duststorm was obscuring the photo survey targets. While waiting for the dust to settle, spacecraft controllers turned Mariner's cameras toward Phobos and Deimos. The first images came in and showed not battered and derelict space colonies, but a view of what could best be described as a "diseased potato". Phobos was "a very cleverly disguised spaceship", one NASA scientist observed wryly. The moonlets looked exactly like many other planetologists had imagined: uneven hunks of space debris, blasted with meteorite craters.

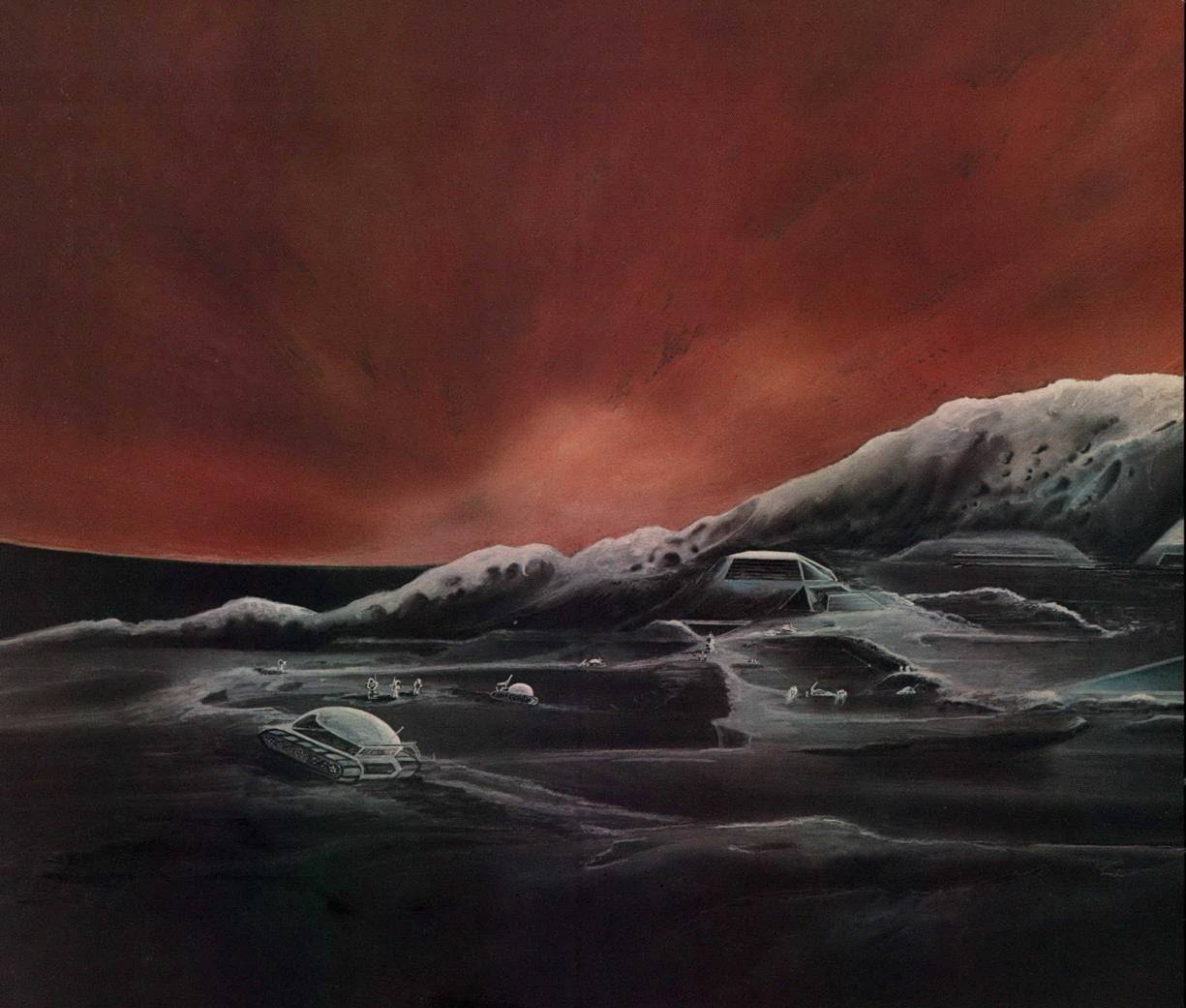
More relevant to the problem of the secular acceleration, however, was the surprising discovery that the Martian moonlets were very dark. Since the size had been calculated presuming normal albedos, Earth based astronomers had seriously underestimated their sizes. Phobos, it turned out, was about 12 miles by 14 miles by 17 miles along its three uneven axes, instead of the pre-Mariner estimate of 10 miles spherical. Deimos turned out to be about 6 miles by 7 miles by 10 miles, compared to earlier guesses of 8 miles across.

So, with a new size in hand, theoretical astronomers recalculated the possible drag effects which had been ruled out by Shklovskiy. Finally, two independent groups in the U.S. and Moscow verified that the tidal interaction between Mars and Phobos was strong enough to account for the speeding up of the small moon. Thus, Phobos became a rocky moonlet again.

The cosmogonists and planetologists were not yet satisfied with these results. First, if Phobos' acceleration were extrapolated backwards in time, some observers claimed it would have had to have left a synchronous orbit around Mars only a billion years ago, after remaining in that orbit for more than three billion years. Second, the figures indicate that Phobos will crash into the planet in some tens of millions of years! This implies that we are now seeing the last one percent of Phobos' lifetime. This is statistically unlikely, though possible. Phobos and Deimos have not been strangers to unlikely coincidences, as we can witness in the Jonathan Swift affair!

Phobos and Deimos From Mariner

After Mariner 9 had introduced scientists to the true size and face of Phobos and Deimos, Viking came along and revealed that not all of the most interesting features had been revealed. With the higher resolution imaging possible in 1976, space scientists were shown even more detailed — and



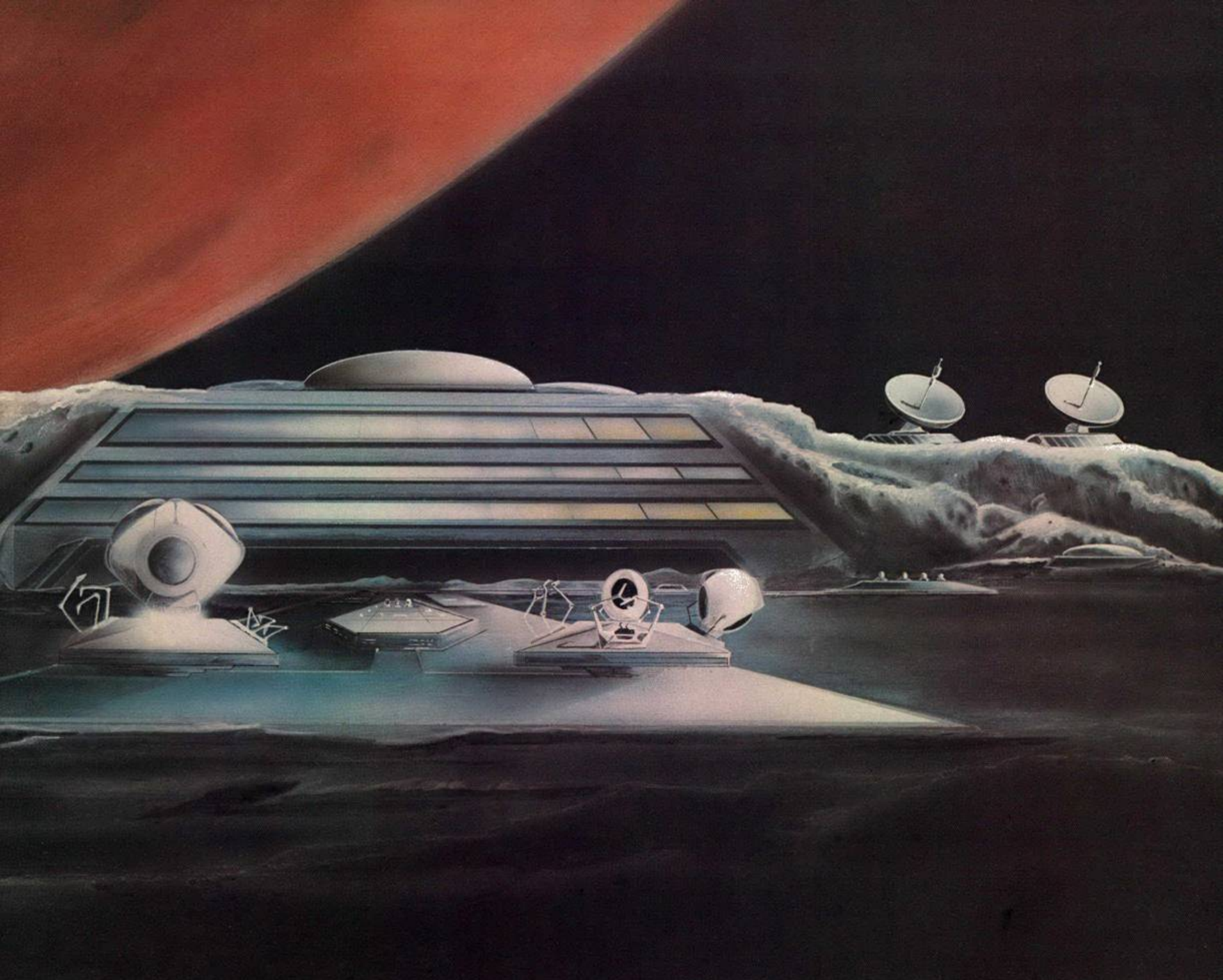
far more puzzling — aspects of the Martian moonlets.

Viking allowed scientists to confirm and extend the crater counts that had been started in 1971-72. Since Phobos, Deimos and Mars had presumably been in the same neighborhood of the solar system for billions of years, they had been subjected to the same flux of impacting objects, ranging in size from interplanetary dust drifting out of the asteroid belt to respectable sized asteroids themselves. Once the "focus effect" of Martian gravity was accounted for (the planet's gravity allows it to reach out and grab passing objects which, but for the gravitational attraction, would have been only near misses), planetologists could compare the crater densities on the satellites with those on the Martian surface. This gave an excellent piece of information about the erosional processes on Mars; these processes had to be destroying the traces of craters that, based on the measured crater densities on Phobos and Deimos, must have one time been formed.

Deimos and Phobos are completely covered with craters. Astronomers term this condition *saturation*; it means that any new crater has no clear place left to form, and new craters must form by overlaying and destroying old craters. This has been going on for at least two billion years, and possibly twice that long. Once a surface becomes saturated, crater counts cannot serve as a measure of increasing age because they do not increase any further — no matter how often the surface is pounded with infalling debris.

Crater structures on Deimos and Phobos were bound to be odd, scientists realized, because of the very low gravity. On larger bodies such as Earth's moon, Mercury and Mars, the force of gravity causes slumping and other forms of structural modification.

Deimos and Phobos may be more important than we now expect if they turn out to be carbonaceous chondrite material suitable for mining. The lighter elements are present in the carbonaceous material, perhaps providing a vitally necessary source of air, water and carbon compounds to space colonies. In this scene, the central control base for "Phobos Mining Colony" provides docking, refueling and communications facilities for the exploitation of this natural resource. Artwork by Mark Paternostro.



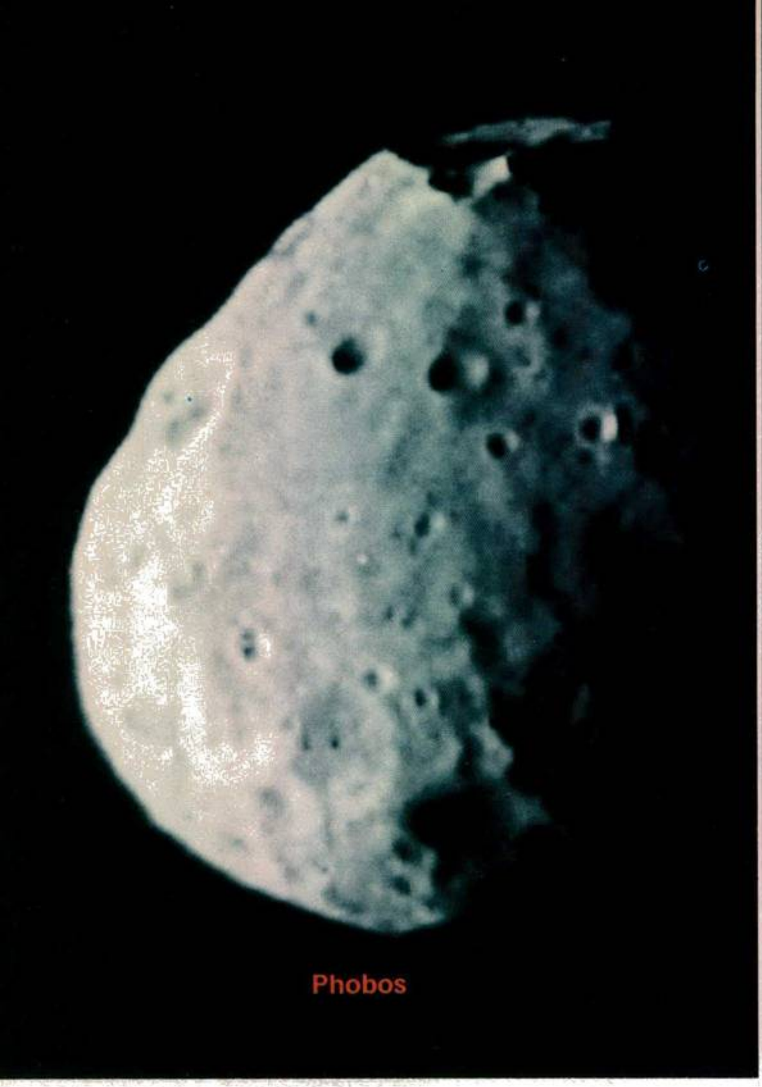
Secondary craters — caused by the fallback of material splashed up by a main impact — are also common. These types of structures were not expected on the Martian satellites.

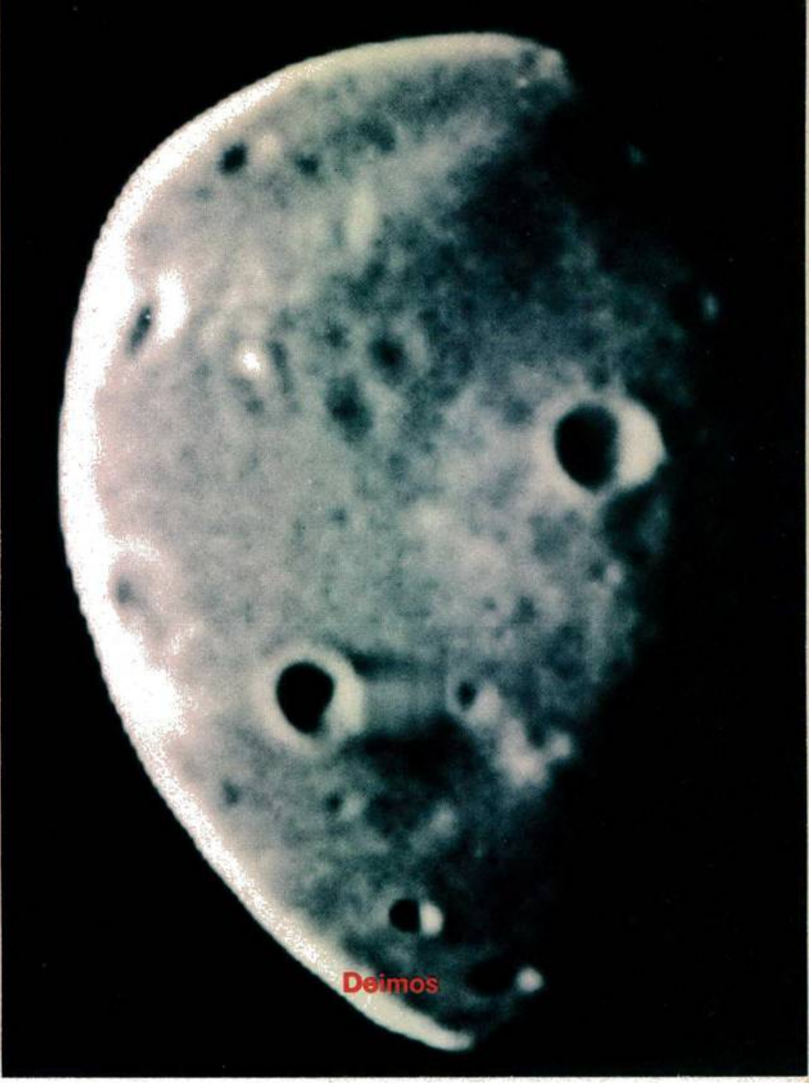
Some of these forecasts did come true. Photographs showed that the interior of large craters were also completely saturated, even on sloping walls (which on Earth's moon would have been wiped clean of craters by landslides). Planetologists have begun to realize that this landslide effect may be responsible for the odd lunar feature of small craters atop central peaks; observers had pointed these features out as obviously volcanically generated craters, since the odds of a meteor hitting only on the top of these peaks were very slight. But in fact, meteors hit *all over* the peak. On the steeper slopes, the craters were obliterated by landslides, leaving only the craters on the relatively level mountaintops to confuse observers.

Completely contrary to predictions, the Viking scientists also found what could only be termed secondary crater chains. Even more puzzling, they found clear striations — lines across the surface of Phobos running parallel to each other and parallel to the plane of Phobos' orbit around Mars. These clusters of irregular depressions in herringbone or chevron shaped patterns are characteristic of secondary craters. All that the scientists now needed was a new theory to explain how the very slight gravity of Phobos could pull crater ejecta back to its surface, following a high speed meteor impact. Even though previous theories did not call for such behavior, something must be re-impacting the surface.

Other data supports this conclusion. Since 1971, scientists have known that Phobos and Deimos were covered with rubble, forming a thin regolith instead of bare rock. This was detected by the infrared sensors on Mariner 9, which measured the cooling rates of the surfaces that moved from sunlight into darkness and back during eclipses.

One immediate source of re-impacting material is, of course, the material that has just been blasted free by an impact. If the impact was not nearly as fast as earlier supposed, and if the surface material was





soft and brittle, then fragments broken free might just still be traveling at less than the satellite's escape velocity. Another source might involve multiple recollisions of debris blasted out on escape trajectories. As fragments circle around the far side of Phobos, they might collide and knock some of their mass back onto the surface. The most noticeable of the secondary craters on Phobos just happen to be on the side of the moon exactly opposite from the largest Phobos crater, Stickney.

Lastly, some brief computations reveal the most likely of the sources of re-impacting material. The escape velocity of Phobos is about 26 m.p.h. (12 meters per second). The escape velocity from Mars' orbit at the altitude of Phobos, however, is more than 2,200 m.p.h. (1,000 meters per second). This means that material blasted free from Phobos will most likely remain in orbit around Mars. More importantly, the orbit of the material will, in many cases, be one that will intersect Phobos again after several years — or several thousand years. At that point, a new impact (a low velocity collision) could occur.

If this mechanism is indeed the source of the secondary craters on Phobos, it has implications for future space missions to the Martian satellites. The meteorite flux in the orbits of the satellites may be higher than elsewhere near Mars. Measurements have not yet confirmed this.

An additional feature of Phobos is still baffling: There are grooves running around the equator of the moonlet (see page 8). Scientists do not understand these formations; the grooves run parallel for miles at a stretch, up and over crater rims, and apparently disappear into the darkness of the night side of Phobos. Possibly they run entirely around the moon. The grooves were either formed on Phobos itself, or they were already a feature of Phobos at the time the moon was formed. This means that some dynamic process in orbit around Mars scoured the furrows into the rock (they seem to be deeper than just the regolith layer) with remarkable precision and regularity (no two grooves can be seen to intersect or cross). On the other hand, they may represent layering in the parent body, of which Phobos is only a fragment. The latter theory must account for the fact that the grooves today are aligned parallel with the orbital plane of Phobos (and the equatorial plane of Mars). The former theory must propose a method for sculpting the grooves. Scientists are not happy with either choice, but they are delighted with the unexpected mystery.

Other features that are even more poorly understood on Phobos are associated with craters: Some craters seem to exhibit central peaks — a feature which, on larger worlds, is associated with isostatic rebound of the crater floor (a process intimately connected with gravitational compression, which does not exist on Phobos). Also, some irregular, elongated depressions start at some crater walls and then taper out as they get farther away from the crater. Planetary geologists have never seen such structures before and do not know how they form.

The study of crater formation on essentially gravity-free objects has only begun, and it will have profound implications in the study of the general cratering process. A recent suggestion that central peaks may be associated with closely spaced double impacts is intriguing until one realizes that the disintegration of an incoming object — a frequent occurrence, as seen in terrestrial, lunar, Martian and Mercurian impact features — has been blamed on gravitational stresses. This again rules out such a process anywhere near weak Phobos.

Observations of the Martian satellites have been carried out at many wavelengths. With albedos of about six percent, they are among the solar system's darkest objects. (The albedos of Phobos and Deimos are approximately the same.) Mariner 9 detected brightness variations of about 30 percent on their surfaces, which could be attributed to different particle sizes in the regolith or to dissimilar chemical compositions of different regions on the surfaces. Observations in the infrared and ultraviolet made from Mariner 9 are being combined with readings taken by different instruments on the Viking orbiters. Together, this data will help determine the reflectivity characteristics of the regolith across a broad range of wavelengths, and hence its possible composition.

The preliminary results from Viking say that the darkness of the regolith is fairly independent of particle size, implying a very opaque surface material: The primary suspect is carbon. It may be that Phobos and Deimos are covered with carbonaceous chondrite material, though it does not imply that they are made entirely of such material. Carbonaceous chondrite materials are found in many meteorites and must have formed farther out in the solar system than the orbit of Mars. Many asteroids, for example, are composed of carbonaceous chondrites with light curves similar to those of Deimos and Phobos.

One experiment soon to be performed will be needed before we can measure the masses of the two moonlets, and thus differentiate between carbonaceous chondrite composition (which would require a density about twice that of water) or basaltic composition (which would require a density of about 3-1/2 times that of water). Whichever it may be, or whatever intermediate combination it may turn out to be, it will have a major impact on the theories of moon formation and solar system formation in general. The experiment involves a close fly-by of the satellites by the Viking 1 orbiter in the spring of 1977. The spacecraft will be sent past both moons at a range of perhaps 30 or 40 miles, and the gravitational deflection of Viking by the moon will be measured. This will allow a determination of the mass of each object. Since the volume can be calculated from the photographs, a good estimate of density — to within 10 percent or so — can be made.

Formation of the Martian Moons

Where did Phobos and Deimos come from? Two types of answers exist: They formed in their present orbits (but from what?), or they were captured by Mars after forming elsewhere (but how?). Like so many simple theories that astronomers hoped would be confirmed or disproved by new data, both these hyotheses are still equally viable. Unfortunately, new data has suggested that neither of these theories is likely. But no new theories explain this yet either.

The fact that both moonlets are of such an abnormally low albedo does suggest a related birth, since in a random selection of captured asteroids, both would probably not be of almost precisely the same brightness. Unfortunately, the actual albedos of all asteroids that were available for Mars capture billions of years ago might just have been very dark. Alternately, a single object might have been captured that later broke into two or more pieces.

The major argument against capture is the nearly circular orbits of both moonlets. In addition, both nearly line up with the Martian equatorial plane (inclinations of about one degree at most), and not with the plane of the Martian orbit or the ecliptic. To explain the transformation of the initially highly elliptical, highly inclined captured orbits into the circular equatorial orbits is not easy. Since the satellites are now in such orbits, they probably formed in similar orbits.

If they formed near Mars, the next question is where their parent material came from. Here a number of choices are still being considered. The material could have been left over from the formation of Mars itself, or from fragments of a larger Martian satellite that broke apart. Alternately, the source might be asteroidal material that gradually formed a dust cloud or planetary ring and then coalesced into small objects.

An interesting theory about the formation of the planets concerns the original angular momentum of each planetary cloud of debris that eventually formed into a planet and its family of satellites. The angular momentum of Earth, Jupiter, Saturn, Uranus and Neptune is surprisingly similar, according to this theory, and the angular momentum anomalies of Mercury, Venus and Pluto can be accounted for by their tidal and gravitational histories. But Mars is a puzzle.

Mars, according to this hypothesis, should be rotating at least four times as fast as it is today. Alternately, Mars would have had to own a large moon that could have absorbed the excess angular momentum. The moon was lost when it was smashed by a passing asteroid, and most of the fragments escaped, leaving only a few. Deimos and Phobos would be the sole survivors.

The *angular momentum* theory is still a theory, but it points out the relative intertwining of solar system data and the importance of Deimos and Phobos to the understanding of the evolution of the solar system as a whole. If the Viking data indicates that the two moonlets are indeed fragments of a much larger body that formed in orbit around Mars — a protomoon perhaps 1,000 miles or more in diameter — then the angular momentum theory will have received a strong boost and can be more confidently applied to problems in other areas of the solar system.

Since it does seem that Phobos is moving in toward Mars, and Deimos is moving out, it is plausible to surmise that we are seeing the last survivors of this cataclysm. (The "divide" is at the point of synchronous orbit around Mars where the satellite would stay over the same point on the surface below; for Mars, this distance is 6.1 diameters from the center of the planet.) Mathematically it is unlikely that any satellite beyond this point may have been able to escape from Mars in the age of the solar system, but it does seem plausible that other satellites inside that limit could have decayed and impacted on Mars.

This is both a problem and a puzzle. All the major Martian impact basins are far north or south of the equatorial regions, where the impact would have taken place. A suggestion that the Martian poles have shifted over the eons is flatly contradicted by the probable great age of the aeolian and ice deposits of the present polar regions. The one major Martian feature which is in the equatorial region, and which just happens to run on a generally east-west course, is the awesome Valles Marineris. The notion that infalling Phobos sized moons may have contributed to the formation of this structure has been suggested, but has not been taken seriously by Mars geologists.

One problem of the disintegration of any hypothetical thousand mile diameter protomoon of Mars is that it would have needed an impacting object several hundred miles across. The basins of Hellas, Moeris Lacus, the south polar area, and Argyre do suggest that asteroids of that size did impact on Mars in the past, so many more may have hit and had their traces obliterated by erosion, while even more flew past Mars. A comparison of theories of mass distribution in the early solar system, as confirmed by crater counts on the moon and Mercury, does suggest that any protomoon of Mars would have a very large probability of being fragmented by a passing asteroid during the first few hundred million years of the solar system

But where did all the rubble go? If it remained in orbit around Mars, it would probably re-accrete to form another large moon in less than one million years. Without some way of removing all but 1/1,000,000 of the mass (which remains as Phobos and Deimos), this theory is stuck. Scientists hope that new data from Viking will either revive or retire the protomoon theory.

Future of the Martian Moons

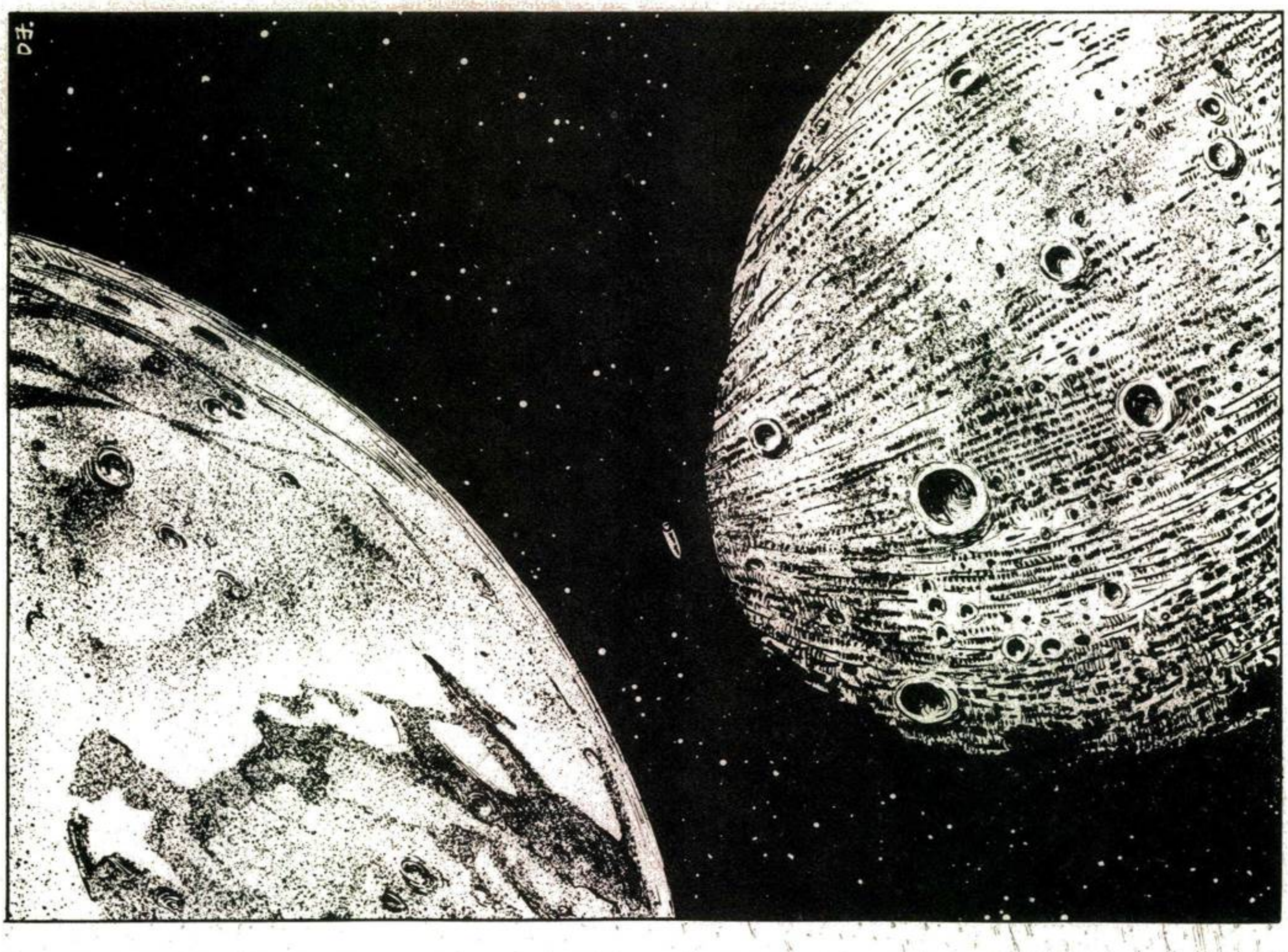
Deimos and Phobos may have important roles to play in the future of space exploration and space colonization. Since they are about the easiest objects to land on beyond the Earth-moon system, they may be the next worlds to be touched by astronauts. They can provide stable observation platforms for Mars exploration. They will provide information about the material and energy environment of regions of space near the asteroid belt. And sometime in the 21st century, they may provide some of the material resources with which space pioneers will construct giant artificial worlds that may rival Deimos and Phobos in size.

Since the gravity of the moonlets is so weak, a landing on either one would more correctly resemble a docking of two spacecraft. An object falling to the ground from above Phobos would hit with a speed of about 30 feet per second — about the impact of a baseball in a catcher's glove. (Phobos spins with a speed of about seven feet per second at the equator.) Some type of rocket braking is probably desirable for delicate spacecraft, but hardened instrument packages could be dropped from passing spacecraft to hit the surface directly.

Today the major consumable item that limits the lifetimes of artificial Martian satellites (like Mariner and Viking) is the supply of stabilization gas needed to keep the spacecraft steady, so that its instruments can point at Mars and its radio antennas can point at Earth. If such a vehicle were placed on one of the natural satellites, it would face the planet continuously without the expenditure of any fuel at all! Small electrical servo-mechanisms could keep its antennas tracking Earth during the periods when Earth was visible. (For Phobos, this would be about 40 percent of the time; half the time Earth would have "set", and during the remaining time Earth would be occulted by Mars.)

Two engineering problems of such Mars observation stations are power and thermal control. Deep space is more benign in environment than a planetary surface, since sunlight is almost always available and there are few extreme sudden changes in local radiant energy — except for brief periods when the spacecraft flies through a planet's shadow. Sunlight reflected into the spacecraft from the surrounding landscape would make it hotter to sit on Phobos; the constant day-night-day cycle of temperature extremes would make it harder to keep the instruments within an operating range.

If Viking results warrant a follow-up Viking 3 mission, it would be possible to modify the spacecraft to make very close passes of Deimos and Phobos. A slight enlargement of the orbiter's fuel tank would allow it to loiter within 20 miles of either moonlet for several hours at a time, obtaining superb high resolution photographs of puzzling surface features.



Man's first exploration of the Martian moons may occur late in this century or early in the next. The mission shown here is a 1990s explorer — looking much like the Apollo lunar exploration craft of the 1960s — shortly before "docking" on the surface of the tiny moon to gather samples. Since Phobos' surface gravity is so slight, only minimal difficulties should be encountered. Artwork by Dan Frederickson.

The impact velocity of an object falling onto Phobos is also comparable to the speed at which parachutists hit the ground. This suggests that astronauts as well as instruments could be dropped onto the moonlet. The main spacecraft could remain in orbit about two or three miles high, taking several hours to make each revolution. Retrieval of the crewmen could be carried out by means of techniques already developed for the recovery of downed jet pilots in jungles and oceans: A cable several hundred feet long could be thrown into space (on Earth it's supported by a helium balloon), and the mother ship could make a low pass over the base cap to snag the cable. The crewman would be hooked to the other end and would be pulled back into space, to be reeled in like a fish. Or, small rocket belts already used for point-to-point transportation could carry the crewman into orbit. Rocket belts will probably be the only feasible means of getting around on the surface of Phobos and Deimos, since standard walking techniques will not work: There is not enough gravity to provide the frictional footing needed to push yourself across the surface.

If the Martian moons are carbonaceous chondrite material, or even contain only a fraction of such material, they could be of enormous commercial value in 30 or 40 years. Plans for the development of giant space colonies call for use of resources from Earth's moon for construction materials such as metals and silicates. Unfortunately, the volatile elements such as carbon, nitrogen and hydrogen are unavailable in useful concentrations on the moon, and must therefore be transported from Earth. Fighting against the tremendous pull of Earth's gravity would increase the cost of the materials and hence gravely threaten the economic viability of space industries. (It takes 25 times as much energy to get from Earth into space as it does from the moon into space.)

The scientific values of space objects cannot be measured by their size or weight, however impressive may be the secrets of the sun, Jupiter, or even Mars. The scientific benefits of studies of tiny Deimos and Phobos may make these two Martian moonlets the most cost effective (at least by mass!) pieces of solar system matter ever discovered.

As with any scientific frontier, Mars and its satellites have proved even more surprising than we had thought. Were we ever to reach the point where we would know exactly what to expect from our space probes, the rationale for such exploration would evaporate. If the results from Deimos and Phobos are any indication, we are an extremely long way from reaching that point.

NEW COLOR PHOTOS OF GALAXIES

by

Laird A. Thompson

In the 1940s, the late Dr. Walter Baade recognized that the Milky Way galaxy is composed of several systems of stars, each having a characteristic color. The oldest stars in our galaxy are concentrated in the red bulge of the galactic nucleus, while the youngest and bluest stars are found in the associations and clusters near our sun. Today we know color differences are indeed very useful indicators of the ages of stars. By studying the color distribution within a galaxy, it is possible to tell something about where its stars were formed in the past and where stars are forming in it today.

The accompanying photographs in this article show just how colorful galaxies are. These pictures were produced with the use of a new and unique computer system being developed at Kitt Peak National Observatory. The system, called the Image Picture Processing System (IPPS), links a color television display monitor with one of two computers. This system now provides astronomers with a flexible method for displaying and analyzing pictures.

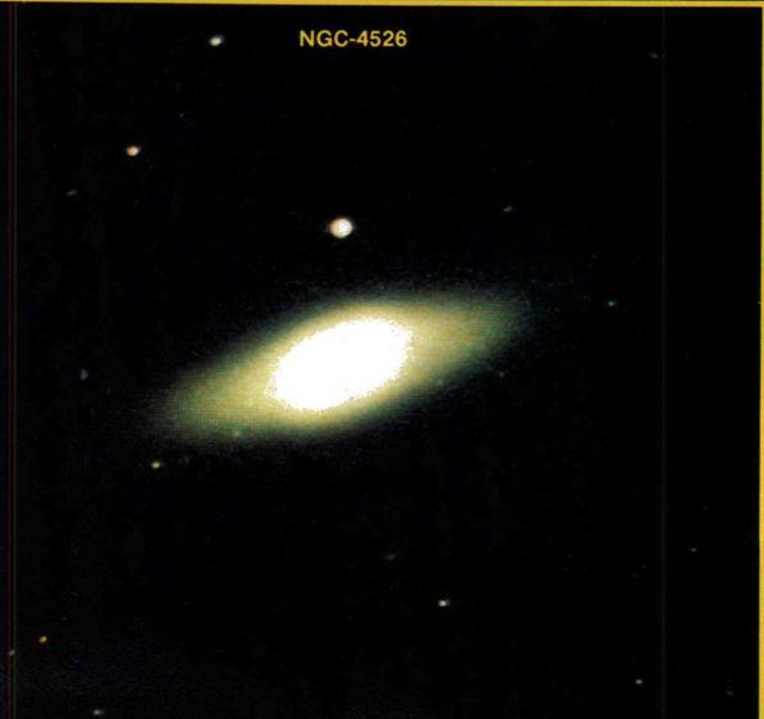
To reproduce each of the galaxy photographs shown with this article, three separate pictures were read into the IPPS — one for each of the three color phosphors of the TV monitor. The picture displayed on the red phosphor comes from a black and white negative that was originally exposed at the telescope behind a red filter. Since only the red light from the galaxy was able to pass through the filter, the negative shows only the red features of the galaxy. The picture displayed on the green phosphor of the TV monitor comes from a separate photograph that was exposed at the telescope behind a green filter, and it shows only the green features of the galaxy. Again, the picture displayed on the blue phosphor comes from a photograph exposed behind a blue filter, etc. When the three pictures are displayed simultaneously on the IPPS TV screen, the result is a realistic color composite. By adjusting the relative intensities of the three phosphors, the proper color balance can be obtained. To demonstrate the technique, four photographs of NGC-4567/68 are shown on page 22. Three separate single color pictures can be seen, and then the final color composite is shown.

By now you may want to ask, "Why not use color film and avoid all this complication?" For scientific research purposes, color film is rarely used. Astronomers prefer to use black and white photographic plates (or film) because color film is less efficient, and is difficult to develop and analyze. To study any color effect, astronomers compare separate black and white exposures taken behind carefully selected color filters. The galaxy pictures shown here were reconstructed from photographs taken with the large Schmidt telescope at Mount Palomar and the 158 inch (4 meter) telescope at Cerro Tololo Inter-American Observatory in Chile. These photographs are being analyzed in a collaborative research project directed by Dr. Steve Strom of Kitt Peak, studying the structure and evolution of galaxies in rich clusters. The galaxies in these photographs are members of either the Virgo or Centaurus clusters of galaxies.

This exciting new color image of the galaxy NGC-4603 was made using the IPPS machine at Kitt Peak National Observatory in Tucson, Ariz. Three black and white images were "read into" the IPPS. Their tonal values were adjusted by computer, and the color result was photographed from a high quality television screen. All photographs in this article are from Kitt Peak National Observatory, copyright© Association of Universities for Research in Astronomy, Inc.

NGC-4603

NGC-4650



NGC-4526

NGC-4647 and 4649

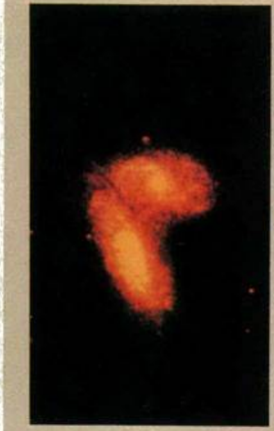
NGC-4501

NGC-4535

NGC-4559

NGC-4569

NGC-4548



RED IMAGE

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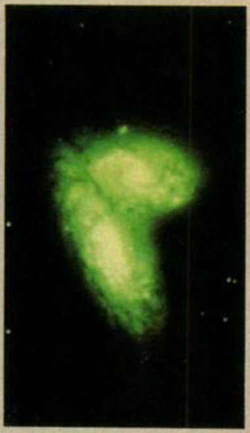

GREEN IMAGE

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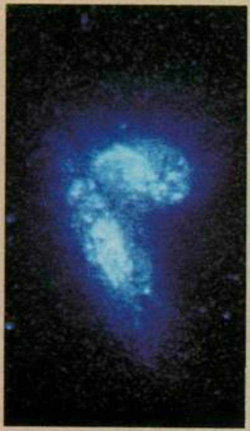

BLUE IMAGE

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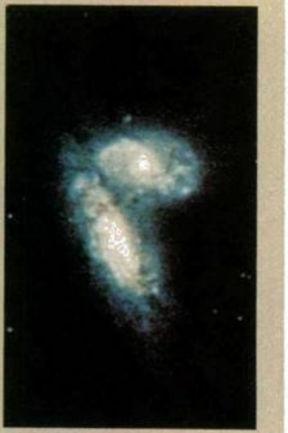

NGC-4567 and 4568

How Is It Done?

Color films are rarely used for research purposes by professional astronomers. Instead, black and white photographic plates (or films) are used, and any color effects are studied by taking exposures behind carefully selected color filters. Although the resulting B&W negatives are esthetically less pleasing than their color counterparts, B&W photographs are easier to develop and much more straightforward to analyze.

Recovering a spectacular color picture, however, from the B&W negatives is possible if three photographs have been made, each through an appropriate color filter — one blue, one green or yellow, and one red. A reconstructed color photo can be made in the darkroom by exposing a single piece of color film successively to the three negatives using the correct color filter with each negative.

Another method for reconstructing color photographs is now available at Kitt Peak National Observatory. A new device, the IPPS, makes it possible to display photographs on a color television monitor. Since the three colors of the television system can be controlled independently, a composite color photograph can be made by simultaneously displaying the blue-filter photograph of an object on the blue phosphor, the green-filter photograph on the green phosphor, and the red-filter photograph on the red phosphor. The relative intensities of the blue, green and red pictures can be adjusted independently, so the proper color balance can be recovered with ease.

Each of the three filter images is "read into" the computer via a device that scans and measures the brightness of the image at each point in it. The scans are recorded on magnetic tape to be entered into the computer at a later time. Once inside the computer, images can be corrected and matched for display on a television screen.

Four photographs of NGC-4567/68 shown here demonstrate how the reconstruction process works. The three component pictures are shown separately, along with the final tricolor composite. Two of the original negatives (the green and the red) were taken behind filters which match very closely the television's color phosphor. The third negative was taken behind an ultraviolet filter; although in the composite picture this image is projected in blue light, the three color intensities can be adjusted to compensate for the slight color shift. The only apparent flaw in the final pictures is the white color of the brightest stars and the galaxy nuclei. (Their true colors cannot be reconstructed for those areas of the photograph which are "burned out" on the original negative.)

Since the relative color adjustment is actually arbitrary, the composite photographs do not necessarily show "true" color — even though every effort was made to match the final color to the expected colors of galaxies. For example, galaxy nuclei are generally very red, and spiral arms are quite blue. Since the latitude for adjustment is small for obtaining reasonable results, the colors are probably very realistic.

Although every galaxy has its own particular shape, there are certain categories of galaxies that seem to have similar characteristics. One category is given the name *elliptical*; galaxies in this class have a spherical or ellipsoidal shape. A good example is NGC-4649, the reddish-green object in the lower portion of the picture labeled NGC-4647/49. Since ellipticals have a relatively simple and plain appearance, only one example is included among the pictures shown here.

The most spectacular galaxies are those known as *spirals*. They usually have a small nuclear region (itself similar to an elliptical galaxy), surrounded by a very colorful flat disk that breaks into spiral arms. The spiral features are easiest to see when the disk is viewed face-on, and is virtually impossible to see when the disk is viewed edge-on.

A third major category of galaxies is called *SO*. These galaxies are similar to spirals since they have a nuclear bulge and a disk, but the disk of an SO is very smooth and featureless. SO galaxies are plain and uninteresting to look at, so only one of these galaxies (NGC-4526) is shown here.

Our own Milky Way is undoubtedly a spiral, perhaps similar to the galaxy NGC-4501. Since our sun happens to lie in the disk of the Milky Way, somewhere near the outer edge and probably in the vicinity of a spiral arm, we see our own galaxy edge-on: a band of light stretching across the sky at night. An attentive observer can see that the nuclear bulge of our galaxy lies in the direction of the constellations Scorpius and Sagittarius, where the disk seems to broaden. Although the Milky Way has colors that are probably quite similar to those of NGC-4501, the colors are not apparent to the human eye since the light from the Milky Way is faint, being spread over such a large area of the sky.

Among all galaxies shown here, the spiral NGC-4650 is the most interesting. The photograph of this galaxy shows that the nucleus of the galaxy is very red, and that the spiral arms are blue-green. Galaxies are made of three major constituents: stars, gas and dust. Stars contribute most of the mass — about 95 percent for spirals, and perhaps as much as 99 percent for ellipticals — and most of the light, too. Since every star has its own color, the color of any galaxy is just the combined color of its stars. Our own sun, for example, is an ordinary star that happens to be yellow. But some stars are blue, some green, and others red. In fact, look at any of the accompanying photographs of galaxies and you'll see that in most fields, there are foreground stars (stars that are our neighbors in the Milky Way), and each one has its own color. The nucleus of NGC-4650 is predominantly reddish because the central region of this galaxy is dominated by red stars. The spiral arms of NGC-4650 have a blue-green hue because the brightest stars in the outer parts of the galaxy are mostly blue or green.

Although a galaxy's color comes mainly from its stars, there are a few highlights produced by the gas and dust. For instance, notice the many small blue patches just outside the nuclear bulge of NGC-4650. These blue regions (called H-II regions) are concentrations of gas. Within the Milky Way galaxy there are similar concentrations of gas; a well-known example is M-42 (the Orion nebula). The blue color in these pictures comes mainly from the bright emission line of the gas at a wavelength of 3727 angstroms. All H-II regions glow only because they are illuminated by bright young stars embedded in the gas.

NGC-4650 also contains clouds of dust. These clouds contribute no light of their own, but they absorb any light that happens to shine through them. Just as dust in Earth's atmosphere makes the yellow sun look red at sunset, the clouds of dust in NGC-4650 make the light from this galaxy look red, too. Notice the very red patches of light near the nuclear region; they are undoubtedly caused by clouds of dust absorbing and reddening the galaxy's light. In the outer parts of NGC-4650, dust is concentrated in long and extended absorption features called dust lanes. Since the spiral arm areas are relatively faint, all the light behind the dust lanes is absorbed, and there is no reddened light shining through. By looking in the other photographs for similar features, you can figure out for yourself which galaxies have dust and which have gas.

Astronomers have made remarkable progress in the last 20 years toward understanding the basic structure of galaxies. Much of the rudimentary work has been completed, but many subtle and important problems remain unsolved. It is clear that some galaxies (the ellipticals and some of the SO galaxies) are made of only very ancient stars, but that other galaxies (the spirals) contain a mixture of stars, both young and old. What we see today is undoubtedly the intermediate stage of an evolutionary process that started billions of years ago. Most astronomers believe that when galaxies originated 10 to 20 billion years ago, these objects were gigantic masses of gas. After an initial collapse phase, the oldest population of stars was formed. It is these stars — which are now mostly red — that make up the ellipticals, SO galaxies, and the nuclei of spirals. But in the arms and disks of spirals (where gaseous nebulae still exist), stars continue to form until the time when the gas they form from becomes completely depleted. As scientific research continues, this picture will certainly be modified and altered. But now it seems clear that we are just on the threshold of understanding how galaxies form and how they evolve.

Dr. Laird A. Thompson obtained his Ph.D in astronomy from the University of Arizona's Steward Observatory, and has since worked at Kitt Peak National Observatory in Tucson. His present research efforts are directed toward understanding the formation, evolution and morphology of both galaxies and galaxy clusters.

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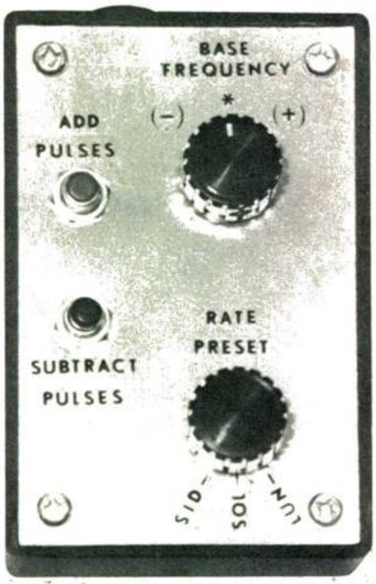

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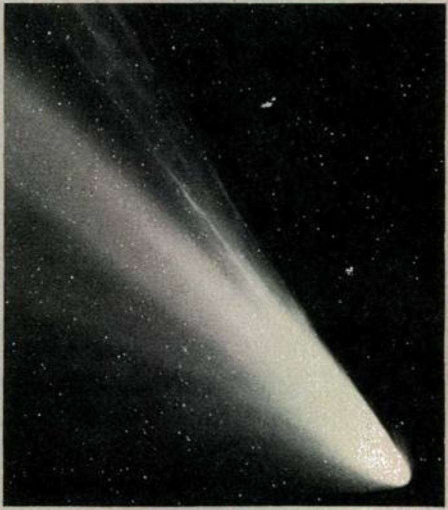

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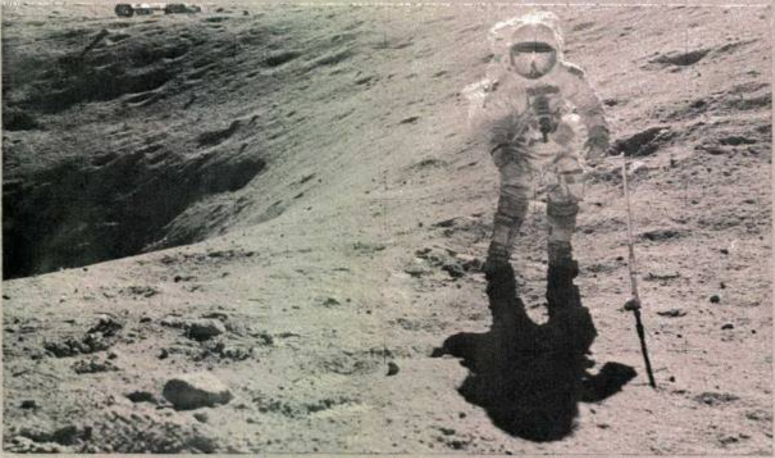

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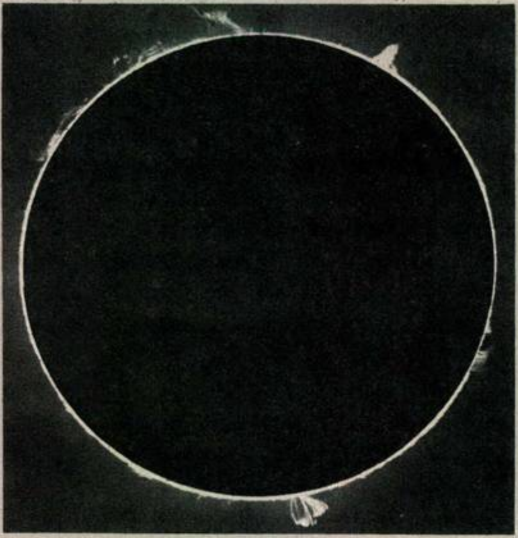

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GAZER'S GAZETTE

Observing From the City

by
John G. Harmon

So you want to be an astronomer, but you say that you live in the city and all you can see are streetlights? Well, take heart — there's still hope! Observing in the city is difficult at times, but not impossible.

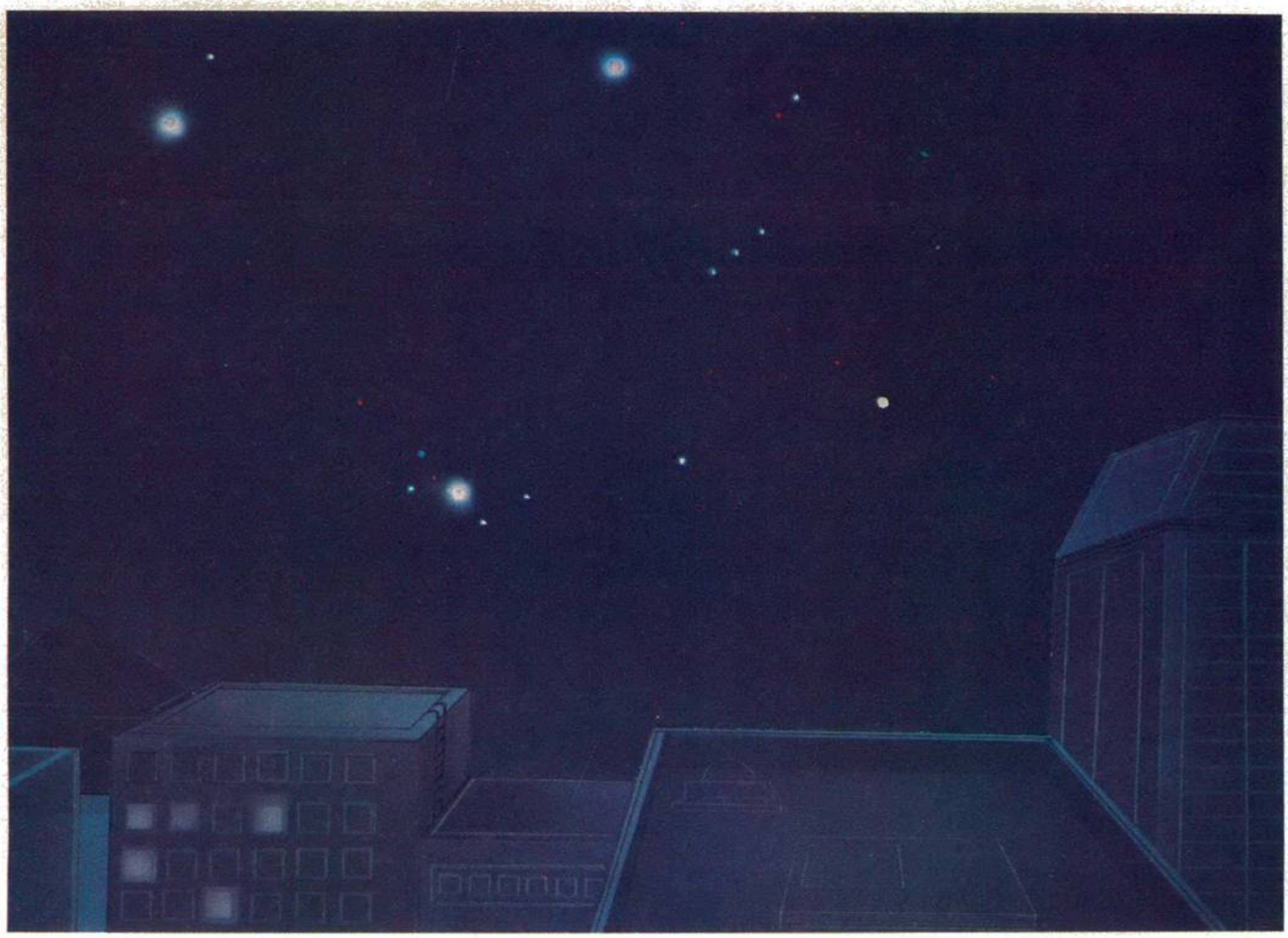
At first, the skies near metropolitan areas appear quite dark, but they are actually suffused with a bluish glow that would be apparent even on a short time exposure photograph. This glow is caused by a combination of city lights and air pollution. The worst offenders are mercury vapor streetlights whose bluish light is more efficiently scattered by the atmosphere, by the same mechanism that makes our daytime sky appear blue. The resulting glow is actually brighter than many of the stars that could otherwise be seen with the unaided eye — which means that only the brightest stars can easily be seen. While the seasoned observer would find this an annoyance, the novice can actually turn it to his or her advantage, for it is these very same bright stars that form the basic patterns of the major constellations.

The ability to locate and recognize constellations is one of the first skills the astronomy enthusiast must develop. While the professional astronomer can find faint objects in the sky by using their celestial coordinates, beginners often have to rely on star charts and maps. Familiarity with the constellations makes translating a position from a chart to a location in the night sky much faster and easier.

There are several ways to learn your way around the night sky. If you are fortunate enough to live near a planetarium, avail yourself of their sky shows; or, ask a friend who knows the stars to be your guide. In either case, and especially if you are working on your own, you will need a set of good *star maps*. Preferably, get the kind that shows the sky as it might appear at any given time of night. The monthly map accompanying Star Dome in ASTRONOMY is a good example of this type. Another good choice would be a *star finder* — a circular map of the sky with a movable mask that can be positioned for latitude, season and time of night. Another important item is a flashlight with which to illuminate the maps. For reasons we'll discuss later, this flashlight should have a red filter. Several layers of clear red plastic will serve this purpose nicely.

Now, armed with your map and red light, you are ready for your introduction to the night sky. When you first look into the sky upon leaving the house, you probably will be able to see only a few bright stars. This is because your eyes are not *dark adapted*. Find a place where you will be shielded from any direct light and wait for a few minutes. Before long, more and more stars will become visible as your eyes become more sensitive. The pupil of your eye is slowly widening, allowing more light in.

After about five minutes, you should be ready. Holding your map (such as this month's Star Dome) with south at the bottom, face in that direction. The three brightest stars in that part of the sky are the winter triangle. Sirius, the brightest, will be almost due south. Betelgeuse, a red star, will be above and to the right, and Procyon completes the triangle to the left. Using your flashlight to illuminate your map, compare it with the sky and



This cityscape depicts one of the best known stellar combinations, the winter triangle. The triangle is composed of three stars of first magnitude: Betelgeuse (upper right); Procyon (upper left), and Sirius (below). Although astronomy enthusiasts usually give up trying to observe within city limits, generally these three stars are bright enough to be visible. Diagram by Mark Paternostro.

pick out the other stars which complete the triangle's pictures of Orion and his hunting dogs.

If, at this point, you had used an ordinary flashlight instead of one equipped with a red filter, you would have ruined your dark adaptation since the pupil of your eye would have contracted because of the sudden increase in the amount of light entering the eye. In this instance, you would have to wait while sensitivity returned. The advantage of red light is that it does not adversely affect night vision, permitting you to look up directly from your map and compare the pictured constellations with the real sky while the pattern is still fresh in your mind.

After you are comfortable with the southern part of the sky, use the same procedure for the west, north, east, and overhead portions of the sky. Be sure to turn the map to its proper orientation as you go along. This is done simply by holding the map with the direction that you are facing along the bottom edge.

In addition to the triangle at this time of year, the Gemini stars (Castor and Pollux), Capella in Auriga, Aldebaran and the Pleiades in Taurus, Regulus and the "Sickle" in Leo, and Alphard in Hydra should stand out. In the north, the Dippers and Cassiopeia should be easily recognized, as they would be at any season — for these circumpolar stars never set. Take a little extra time to learn the location of Polaris, the end star in the handle of the Little Dipper. This star, while not as bright as some others in the area, is nonetheless quite important because of its position over Earth's north pole — a position that makes it nearly stationary in the sky as the stars appear to "rotate" around it.

After several nights, you should have no trouble recognizing the constellations, and you will need to refer to your map less and less. When you feel comfortable with the stars, you are ready for a closer look. All stars have colors ranging from red through orange and yellow to white and blue. These colors are a measure of their surface temperature. Red represents the coolest stars at about 3,000 to 4,000 degrees Fahrenheit, and blue is the hottest at over 25,000 degrees Fahrenheit. Yellow stars like our sun have a surface temperature of about 10,000 degrees Fahrenheit.

This color is sometimes easier to pick up with binoculars. At first you might think that this is due to the star's image being magnified, but this is not the case. Even in the largest telescopes, the image of a star remains very nearly a point because of the star's great distance from us. The binoculars

will isolate a small area of the sky and in some cases make the stars appear breighter — which in turn makes the color of the stars more apparent.

While any good pair of binoculars will work, there are certain kinds that are better suited to astronomical use. One of the best is the 7x50 type. The first number in the designation refers to the magnification (of extended objects) — 7x, in this case. The second number refers to the diameter in millimeters of the objective or front lens, which is 50mm (about two inches). In general, the bigger this number is, the better, as larger lenses will gather more light. For example, a 7x50 will gather twice as much light as a 7x35. Since 7x35 binoculars render a scene approximately as bright as that seen by the unaided eye, a pair of 7x50s will make it appear about twice as bright. This is why they are sometimes called *night glasses*. (For more information, see "Binoculars for Stargazing, Part 2" in this issue.)

Binoculars should be your first piece of equipment and will take you beyond just looking at the stars, to using them to find and examine nebulae and clusters. This is where the fun and challenge of introductory astronomy begins.

Turn back to Orion and locate the three belt stars. Hanging from these belt stars is a sword of fainter stars. Look carefully at the star in the middle of the sword. Is it really a star? Your binoculars will reveal it to be a fuzzy patch of light with some faint stars inside it. This is M-42, the Orion nebula — a birthplace of stars. "But that faint glow doesn't look anything like the pictures of M-42 in most astronomy books," you object. You've just encountered one of the biggest misconceptions that many beginners have: that their view of an object in binoculars or a telescope will be the same as the pictures of that object taken at a major observatory. The sad fact is that the observer's eye simply cannot perceive the faint detail and color that can be recorded on a long time exposure photograph. But even so, there is much that your binoculars will show you.

Above: Obstacles often get in the way of city astrophotographers, so the trick is to use them to your advantage. Trees are used to frame this 12 second exposure of Orion which was photographed on GAF 500 at f/1.8. Photograph by Fred Hafeli. Opposite: Light pollution, a bane to every city observer, makes detailed viewing in the midst of it very difficult. It's often necessary to travel great distances to get away from it. This 26 minute exposure of the Sagittarius sector of the Milky Way was taken from the Kettle Moraine State Forest overlooking Plymouth, Wisc. The photograph was taken with a 35mm camera through a Vivitar 1.9 lens stopped down to f/2.2 on Fujichrome 100 film. Photograph by Martin Eigenberger.

Examine the Hyades and Pleiades: These are stars grouped in open star clusters. The Pleiades appears as a group of six or seven stars to the unaided eye, but about 25 to 30 stars can be seen

Canopus, as it reaches maximum elevation above the horizon, is featured in the center of this photo. Canopus is the second brightest star (Sirius is the brightest), and can only be viewed from southern latitudes. Shining through the trees is second magnitude Gamma Velorum. This 10 second exposure was taken in Dallas, Tex. on High Speed Ektachrome with a 48mm lens at f/2.8. Photograph by John Sikora.

in binoculars. Scan the area between the Gemini twins and Regulus in Leo. Nestled there among the stars of Cancer, almost invisible in the city sky, is a faint patch of light. Binoculars reveal this, too, to be a cluster of many distant suns; it's called Praesepe, or the Beehive.

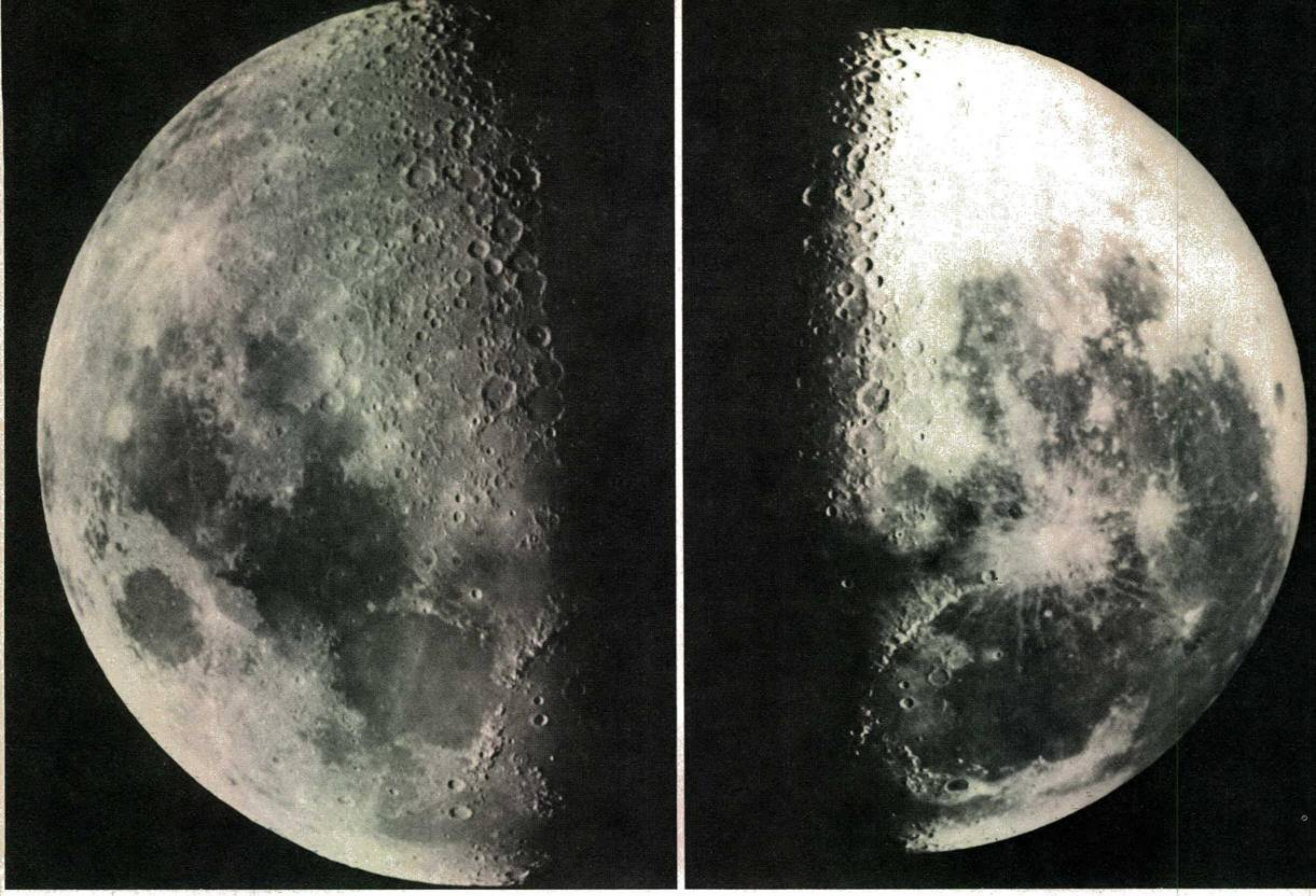
You can also observe certain stars that vary in brightness. A good example is Algol in Perseus, a star that "blinks" every 2 days 20 hours 50 minutes, as a faint companion passes in front of it. From its normal brightness (about the same as Polaris), Algol dims to near the city observer's threshold of visibility. This makes it a binocular object until the eclipse ends, and Algol's normal brightness returns.

If the moon is up, take some time to give it a closer look as well. The image will at first be uncomfortably bright to the dark adapted eye, but eventually you'll find that binoculars will reveal much detail in the craters and mountains. These details are primarily in the form of shadows caused by the sun's light striking the lunar surface at an angle. This means that the period from about three days before, to about three days after, first (or last) quarter is the best time to look. The full moon lacks these shadows and so will not appear as detailed.

The planet Jupiter will also show some detail in binoculars, providing you brace them against something, or fasten them to a tripod. The detail is not on the planet itself, but Jupiter's four largest moons, seen as tiny points of light on either side of the planet. These four were first seen by Galileo in 1610; you can make the same discovery that he did simply by watching them for several nights in a row. Every night their lineup will be different than the previous night's, as these moons hurtle around their giant companion.

A more detailed view than this requires the use of a telescope. Since the purchase of these instruments can represent a substantial investment, a beginner should be sure of his continued interest in astronomy. First explore the observing possibilities of your binoculars. Another option is to get together with others; many cities have astronomical societies or clubs that maintain observatories for the use of their members.

If, however, you decide to get your own telescope, make sure that it is a good one. Many of the inexpensive units on the market today are really only toys whose usefulness in astronomy is quite



The sun's light strikes the lunar surface at an angle, giving it a detailed appearance not evident at full moon. Left: This shot was taken one day after first quarter with Plus-X film exposed for 1/60 second at f/10. Photograph by Steve Reed. Right: Plus-X film exposed for 1/15 second at f/4.3 yielded this photo of the moon approaching third quarter. Photograph by Jack Newton.

limited. A number of articles have been written about what to look for when buying a telescope, and the prospective buyer should research the product carefully. Some special features that the city observer will want to consider include: portability, an equatorial mount, and a good finderscope.

Most city dwellers lack the space for a permanent observatory in their backyard, or feel it's safer to leave their equipment indoors when not in use. A telescope that doesn't need to be completely disassembled every time it's moved can be a great time saver. In addition, such an instrument can easily be taken to the country whenever the opportunity to take advantage of the darker sky presents itself.

An equatorial mount allows the telescope to be moved with the rotation of Earth on its axis, instead of an altazimuth mount which permits only up-and-down and side-to-side movement. Equatorial mounts enable the observer to follow objects across the sky with greater ease. The polar axis of this mount must point at the north celestial pole, approximately marked by Polaris, the "North Star". By this time, you should be familiar enough with the stars to find Polaris quickly and easily.

Lastly, a good finder is essential! Many of the objects you'll be trying to observe are too faint to be seen in the city sky with the unaided eye. While knowing the location of the object with respect to the bright stars will help you to aim your telescope at the right portion of the sky, the final sighting is done with the finder. Because of the faintness of the object, the finder must be capable of delivering a bright, sharp image. Finders are described by the same set of numbers as are binoculars, so the same rules would apply in their selection.

A good telescope with its large lens or mirror will offer the city observer many exciting views of the heavens. But even if you never go beyond the unaided eye and binocular stage, remember that there's still a lot to see. You have the same sky to look at as those who are observing away from the lights and pollution of the city. You just have to try a little harder to see it.

John Harmon is the assistant director of Manfred Olson Planetarium at the University of Wisconsin-Milwaukee. Currently, he is a planetarium specialist teaching courses in astronomy and astrophotography to adult and school groups. His major interests include electronics and astrophotography, specifically the relation between the two.

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DUSTSTORMS OF MARS

by
Sherwood B. Idso

Among the many intriguing aspects of Mars that scientists hope to learn more about during the Viking mission are the Martian duststorms. Every 10 years or so, the entire planet becomes enveloped in a giant global duststorm that makes the wildest descriptions from the **Arabian Nights** seem "pale" by comparison.

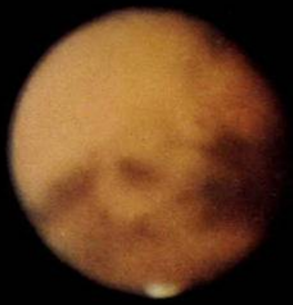
Although scientists have been aware of the Martian Great Duststorms for over 100 years, the general public did not really care about them until late 1971. At that time, Mariner 9 was approaching Mars, preparing to go into orbit and begin its program of photographing the Martian surface. The photographic studies, however, had to be delayed, for the spacecraft arrived just as the planet was shrouded in a blanket of dust. The storm, which Carl Sagan of Cornell University's Laboratory for Planetary Studies has called "possibly the most intense and extensive such storm in a century of visual observation", lasted months before the atmosphere cleared enough to allow surface details to be photographed.

When the dust finally did settle, a multitude of light and dark streaks appeared upon the surface, generally associated with raised-rim craters. During the course of the Mariner 9 mission, areas exhibiting these light and dark streaks were scanned at intervals of days, weeks and months to observe changes. Wind tunnel studies were carried out on Earth to check whether the observed pattern changes were consistent with the hypothesis that some of the dark streaks resulted from wind erosion, and some of the light streaks resulted from deposition of dust.

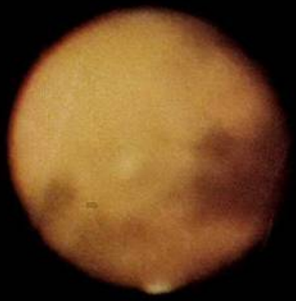
Apparently, the Martian Great Duststorm deposited a thin layer of light colored materials, perhaps less than 1/25 inch (1mm) thick, over much of the planet's surface. Wind patterns in the turbulent wakes of craters removed this material to reveal darker underlying surfaces in some areas, while they piled it up to create lighter looking patches in other areas. Sagan and his colleagues have suggested that similar erosion and deposition processes may be responsible for the well-known seasonal variations in the boundaries of dark areas (long imagined to be covered with vegetation in summer) and light areas (which are supposed to reflect the more inclement conditions of winter). Thus, duststorms have historically played a major role in our curiosity about Martian surface conditions.

With the arrival of the Viking probes, however, we are now ready to tackle the more intriguing problem of the storms themselves — specifically, how and where they form. There are several hypotheses regarding Martian Great Duststorms and how they originate and decay. A theory that has been prominent for several years was developed by P.J. Gierash and R.M. Goody of the Center for Earth and Planetary Physics at Harvard University. They picture such duststorms as self-sustaining, converting solar energy to wind energy on a

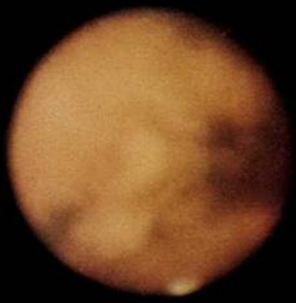
The 1973 Duststorm on Mars



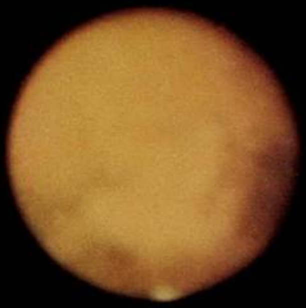
Mars before the storm-surface features were visible



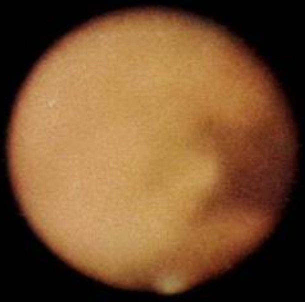
Oct. 13, 1973, the storm erupted



More than doubled in size by the 14th



Spreading rapidly on the 15th



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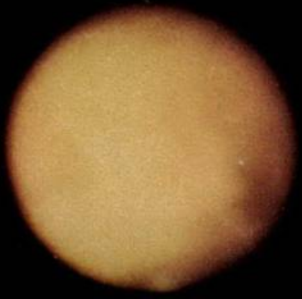

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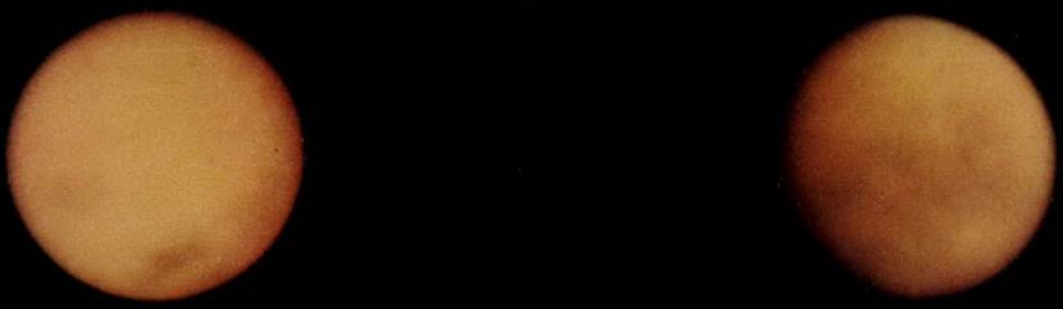
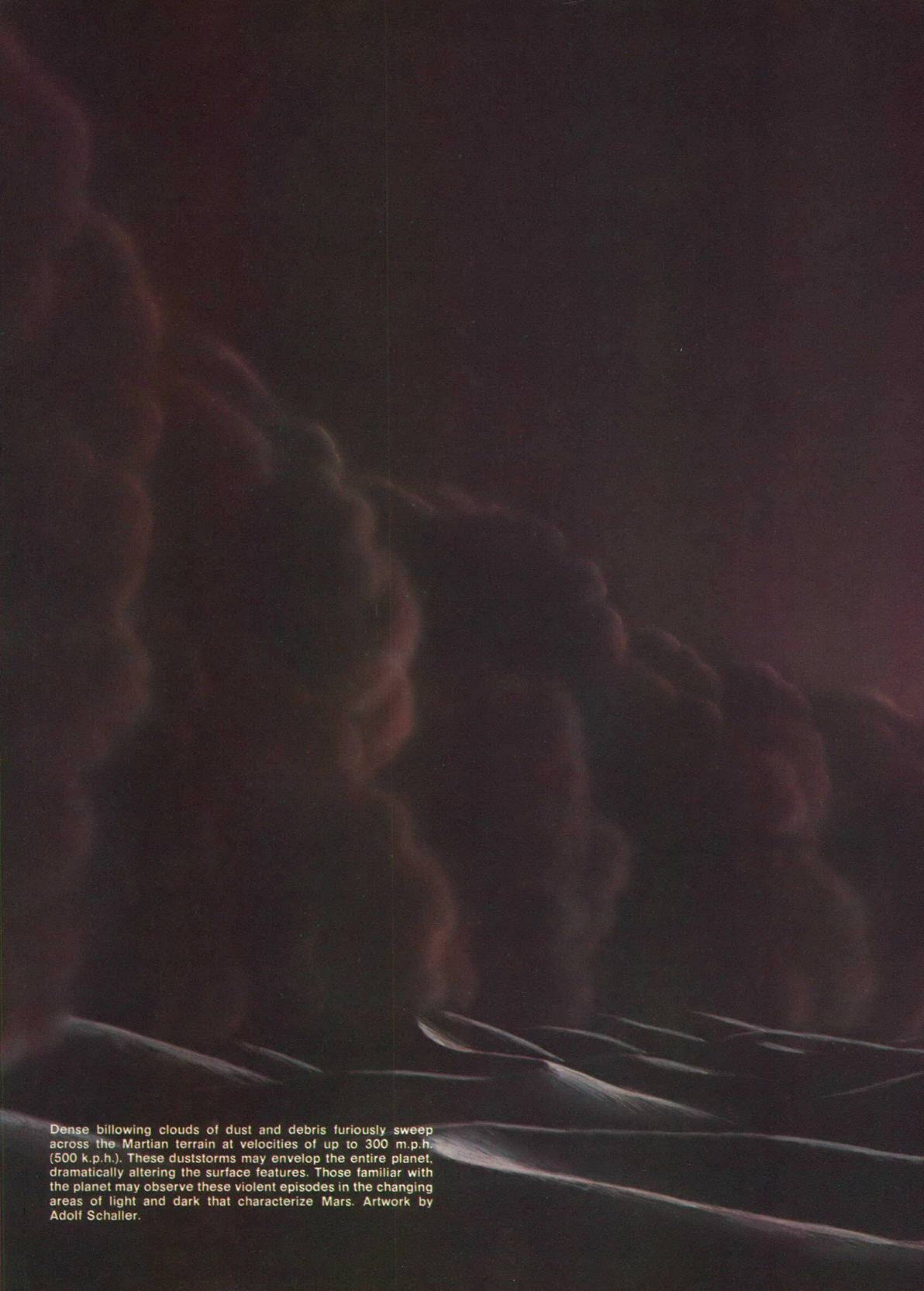
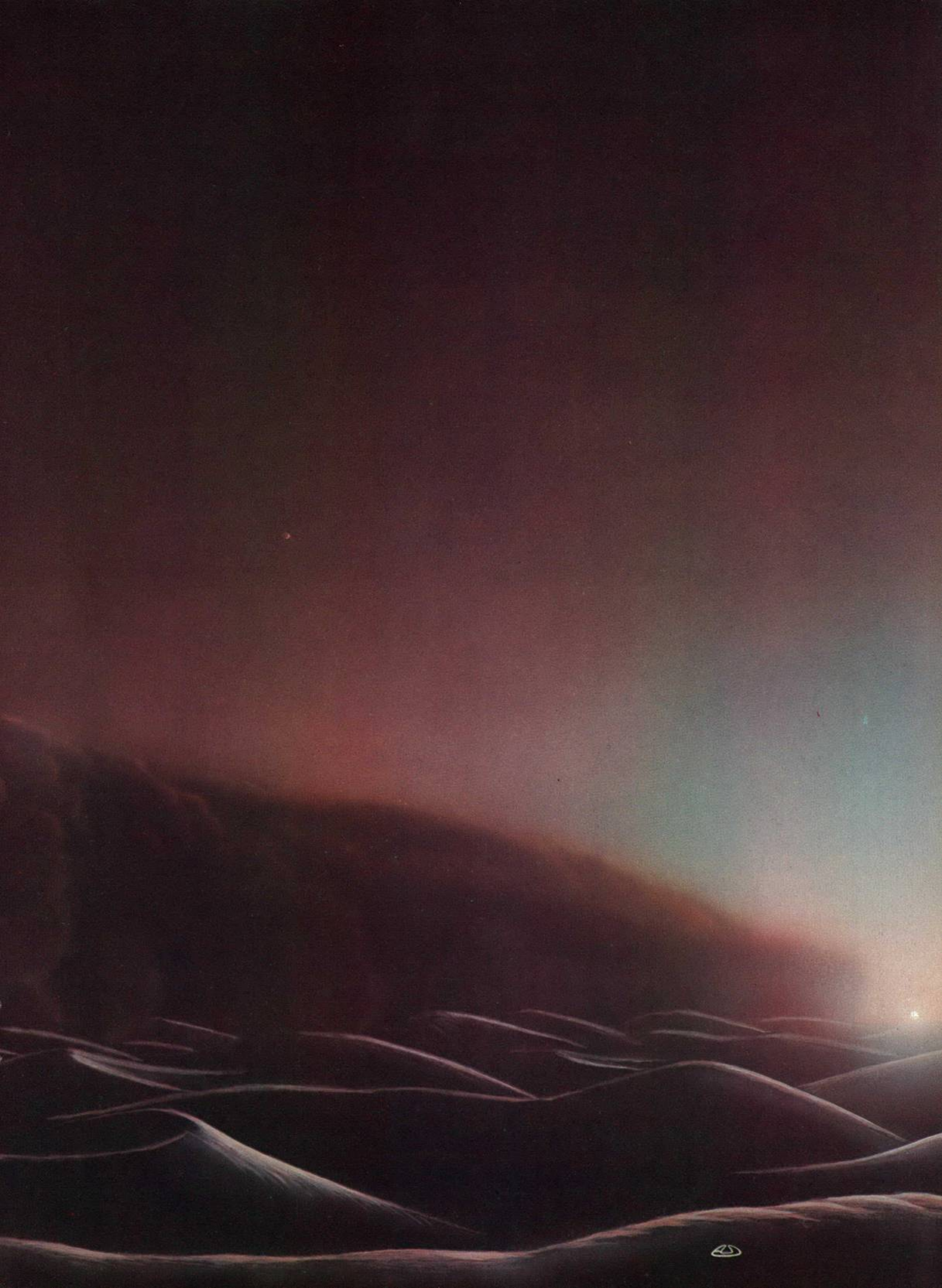


Within 8 days, the entire planet was engulfed in dust. More than a month later, Mars' atmosphere began to clear. Photographs from the International Planetary Patrol Program, Lowell Observatory.



Dense billowing clouds of dust and debris furiously sweep across the Martian terrain at velocities of up to 300 m.p.h. (500 k.p.h.). These duststorms may envelop the entire planet, dramatically altering the surface features. Those familiar with the planet may observe these violent episodes in the changing areas of light and dark that characterize Mars. Artwork by Adolf Schaller.



large organized scale, much like a terrestrial hurricane. Their scenario for the life cycle of such a storm is as follows:

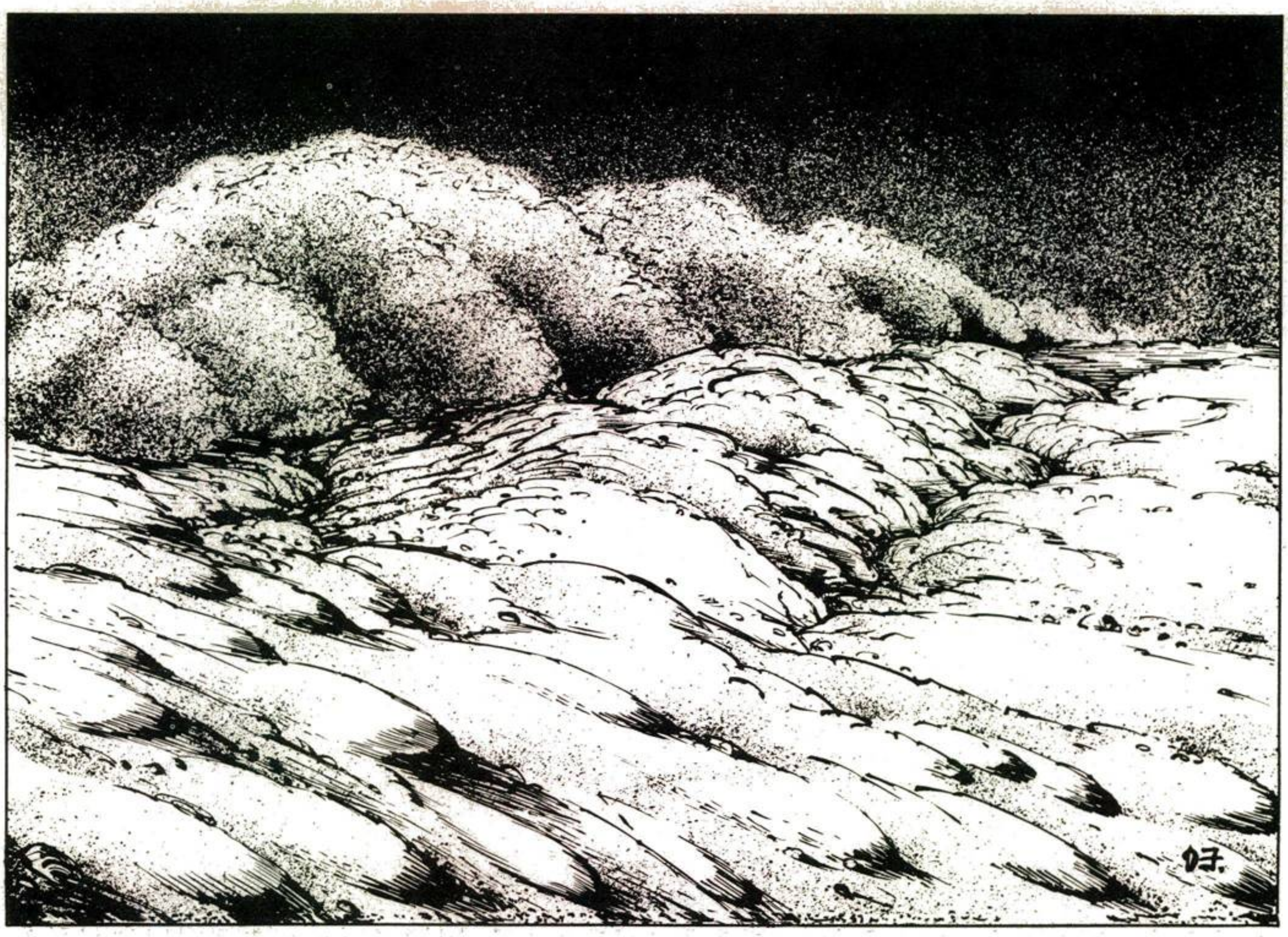
On the high plateau (Hellespontus-Noachis) region during the southern hemisphere solstice, close to the time of southernmost declination (the preferred location and time of nearly all Martian Great Duststorms), the large scale winds that prevail are not strong enough to cause *saltation* to occur; in other words, they don't raise dust from the surface. However, the Martian counterparts of terrestrial *dust devils* may start the process in motion, raising large amounts of dust away from the surface. Once a certain critical density and distribution of dust is attained, solar radiation appears capable of moving the dust and the air around it. This high region is the core of the incipient storm, where a hurricane type circulation pattern develops. Once the winds of the huge vortex reach saltation velocities, they can raise dust directly, so the central core can rise into the stratosphere where the top of the dust column will expand and spread. At this stage it can act as a great pump, spilling fine dust particles into the high altitude winds that can spread the mantle of dust over the entire planet.

The initiation stage of such a Martian Great Duststorm is estimated by Gierash and Goody to take approximately three days, after which the vortex is assumed to continue pouring dust into the stratosphere for about 10 more days. Shortly thereafter, all the dust on the surface is used up (the buoyancy of the central column with respect to the rest of the atmosphere significantly decreases), as the entire atmosphere fills with dust. Then a slow decay stage sets in, with gradual clearing after two to three weeks — although complete clearing may require as long as 150 days.

A terrestrial duststorm sweeps into Phoenix, Ariz., with gusts of wind 60 or more m.p.h. (100 k.p.h.) raising dust from the desert floor. The dust is held in a region of cold dense air flowing downhill, and under the hotter air over the city. Duststorms are typically lobed along the leading edge, with each lobe spreading and expanding forward. The dustcloud here is about 8,000 feet (2,500m) high, and extends for many tens of miles. Photograph by Hamilton McRae III.

The most recent theory about the nature and initiation of Martian Great Duststorms was proposed by P.M. Woiceshyn and A.J. Kliore of the Jet Propulsion Laboratory in Pasadena, Calif. They hypothesize that large duststorms begin on Mars under conditions much like those that raise giant dustclouds on the steppes of Russia, the mountain ringed valleys of Iran, and the high plains east of the United States' Rocky Mountains. In these places, cold air density currents act as triggering mechanisms.

According to this theory, since the largest and longest duststorms generally begin near the Martian perihelion period in the southern hemisphere,



Roaring across the duned Martian surface, duststorms are one of the major influences altering the appearance of Mars. Duststorms raise enormous amounts of the fine material of the Martian surface and carry it for hundreds and even thousands of miles. This scene depicts the preliminary stages of a duststorm as cold and warm air interact, thus giving it the standard classic lobed appearance. Artwork by Dan Frederickson.

coincident with maximum recession of the polar caps, there may be an increase in the average surface pressure of the planet that could lower frictional wind speeds required for dust to be windborne. Second, the great ridge that extends from Mars' southern to northern hemisphere (in a southwest-northeast direction just west of the Hellas Valley) is situated such that morning sunrise occurs along it all at once when Mars is near perihelion. Woiceshyn and Kliore theorize that a pool of cold arctic air from the north would accumulate in this valley, spilling over the ridge when it is heated by the morning sun and down the leeward slopes of Hellas. Once started, the cold gravity current would slide along the ground uplifting warm air in front of it, perhaps further intensified by upslope winds on the sunward side of the morning terminator. In the morning sun, the dustcloud tops could also behave like the surface being heated in the dustfree regions ahead of the front. Strong turbulent spots and vertical uplifting of dust would occur at the dustcloud/clear atmosphere boundary. Thus dust could be held in the atmosphere for long periods of time once it is initially raised, accounting for the longevity of the Martian Great Duststorms.

The scenario Woiceshyn and Kliore have advanced sounds quite plausible. Indeed, there is significant evidence to indicate that it may well be true: Both duststorms in 1971 and the 1956, 1939, 1924, 1911 and 1909 Great Duststorms began in this general area and apparent manner. In the July 1971 storm, for example, observations indicated that a wall of dust more than 30 miles (50km) high swept down the west slopes of Hellas at more than 300 m.p.h. (500 k.p.h.). Mariner 9 photographs also indicate smaller duststorms that look very much like the density current-generated duststorms that occur on Earth.

Whether one of these theories or another explanation for the Great Duststorms is correct, the Viking spacecraft may have something to add. Scientists are looking forward to new data that can be brought to bear upon the subject, and are eagerly awaiting the 1977 duststorm season.

Dr. Sherwood Idso is a research physicist at the United States Water Conservation Laboratory in Phoenix, Ariz.; his areas of study include streams and ponds, planetary climatology, severe weather phenomena, agricultural food production, and remote sensing. His interest in Martian duststorms grew from studying the duststorms of the southwestern U.S.

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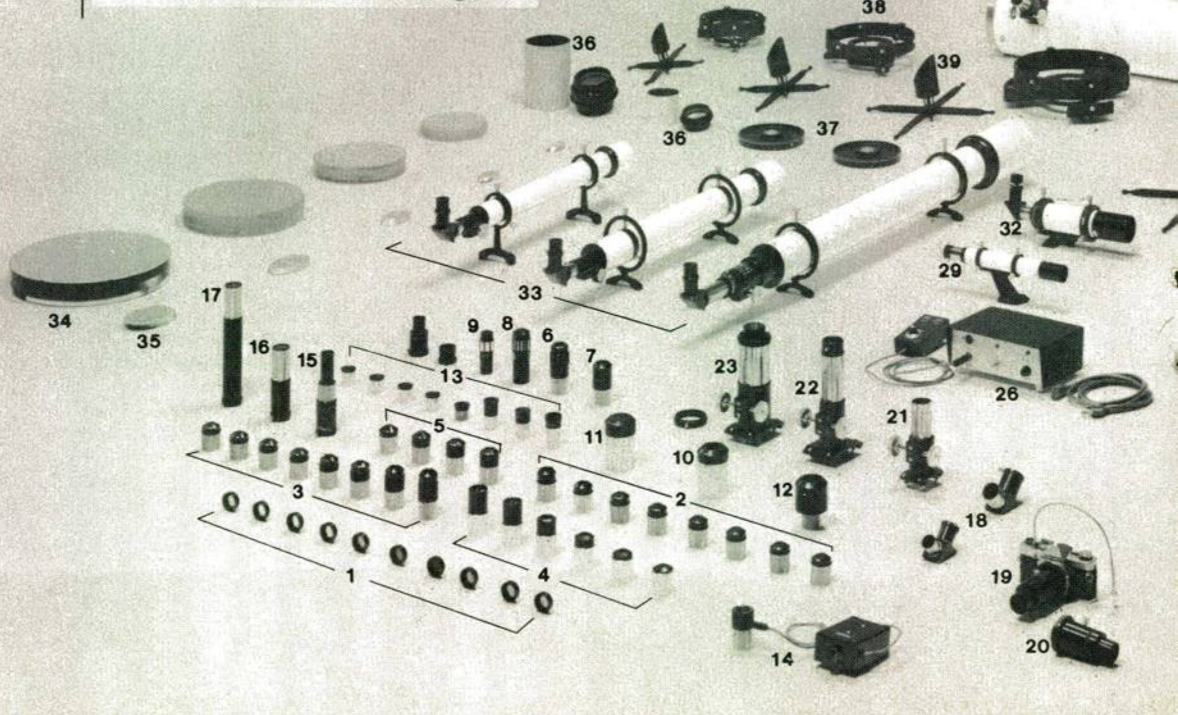

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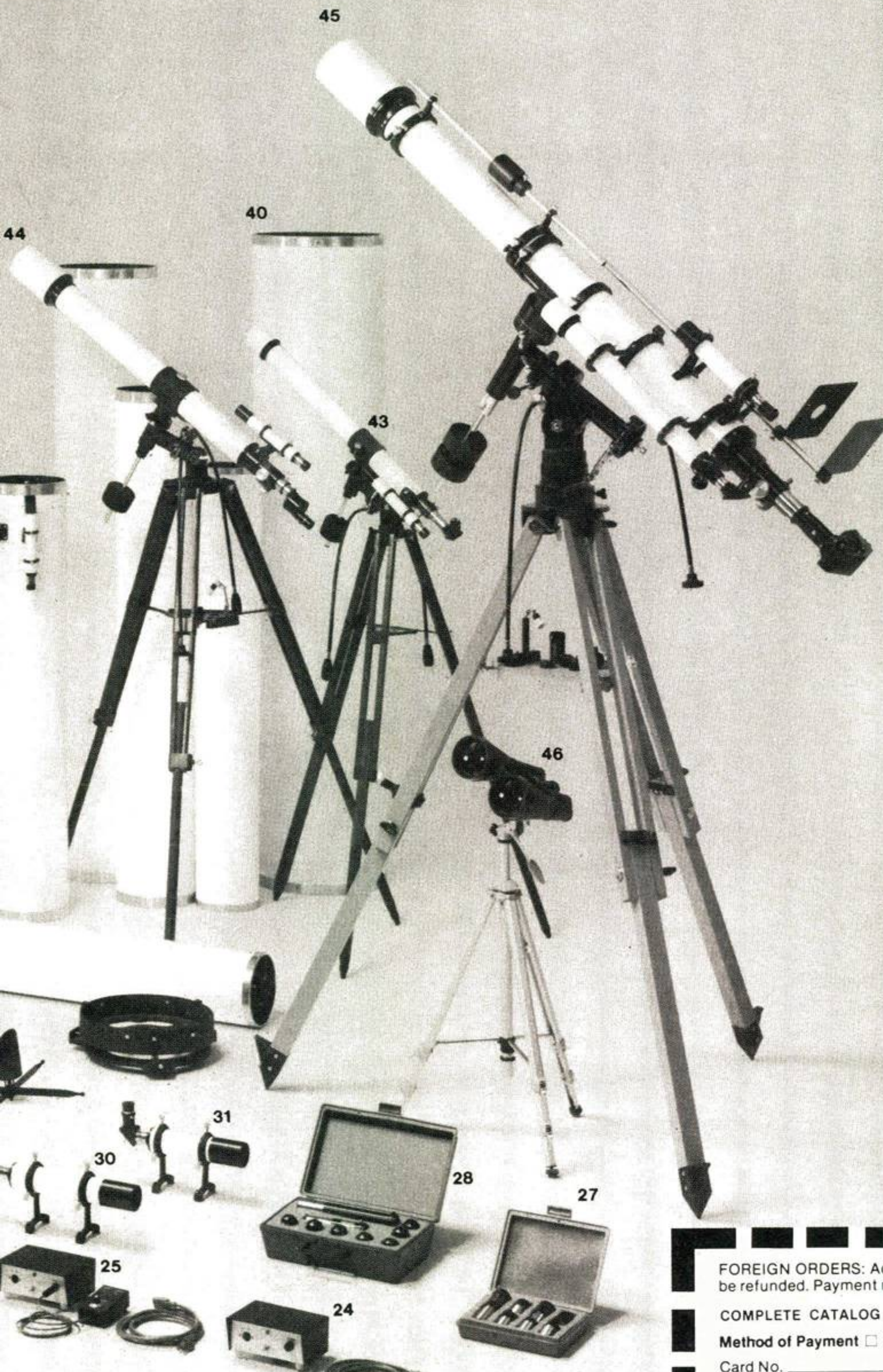

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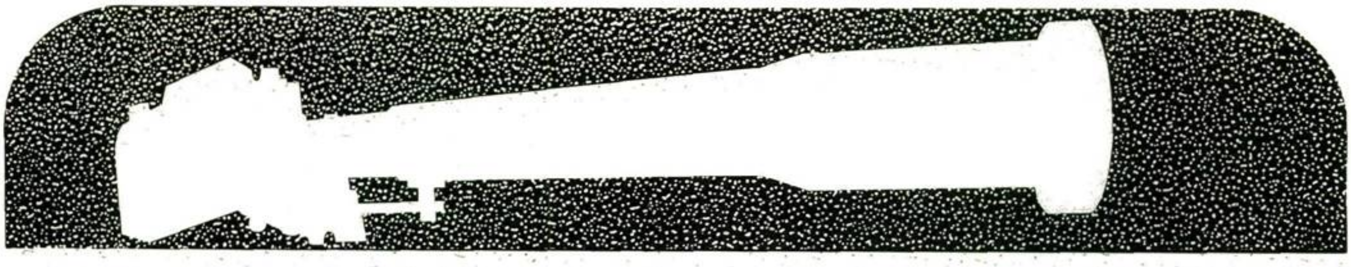


PHOTOGRAPHY IN ASTRONOMY

Cold Cameras: Part 2

by
Richard Berry

Cold camera astrophotography may produce wonderful results, but it has drawbacks too. Although your film is immensely speeded up by being cooled down, you might easily find yourself spending most of your valuable clear sky time sticking to wet or damp film, crushing dry ice, searching for lost parts of your cold camera, or kicking recalcitrant vacuum pumps — rather than taking pictures. You could also find (the day *after*, when you develop your films) that fogging or frosting took place in the camera or on the film, blotches or spots appear on the film, unsightly scratches have crept in, or that dirt between the film and the plug ruined otherwise good photos. You might just find that after a whole night spent hard at work, you only managed to expose one or two films — with the rest of your time spent playing nursemaid to a finicky gadget in the dark. In other words, the results might not justify the work!

How can you beat the system — and get a cold camera to produce as efficiently as ordinary warm films — to avoid the hassle of wasting half the night (or more) fiddling around? The secret is organization: You must be prepared and equipped for the problems. The best solution is to bring a friend along with you who can get the camera and film ready for the next shot while you're exposing this one. It seems so obvious that no one even thinks of it — except successful cold camera astrophotographers!

Your job (or your friend's on alternate nights) is to focus, guide, and handle all aspects of the telescope; your cohort's job is to unload exposed film, warm and dry camera parts, load fresh film, and handle all aspects of the cold camera. The camera will always be ready, the telescope won't sit idly, and you'll have somebody to chat with as you while away the hours spent guiding.

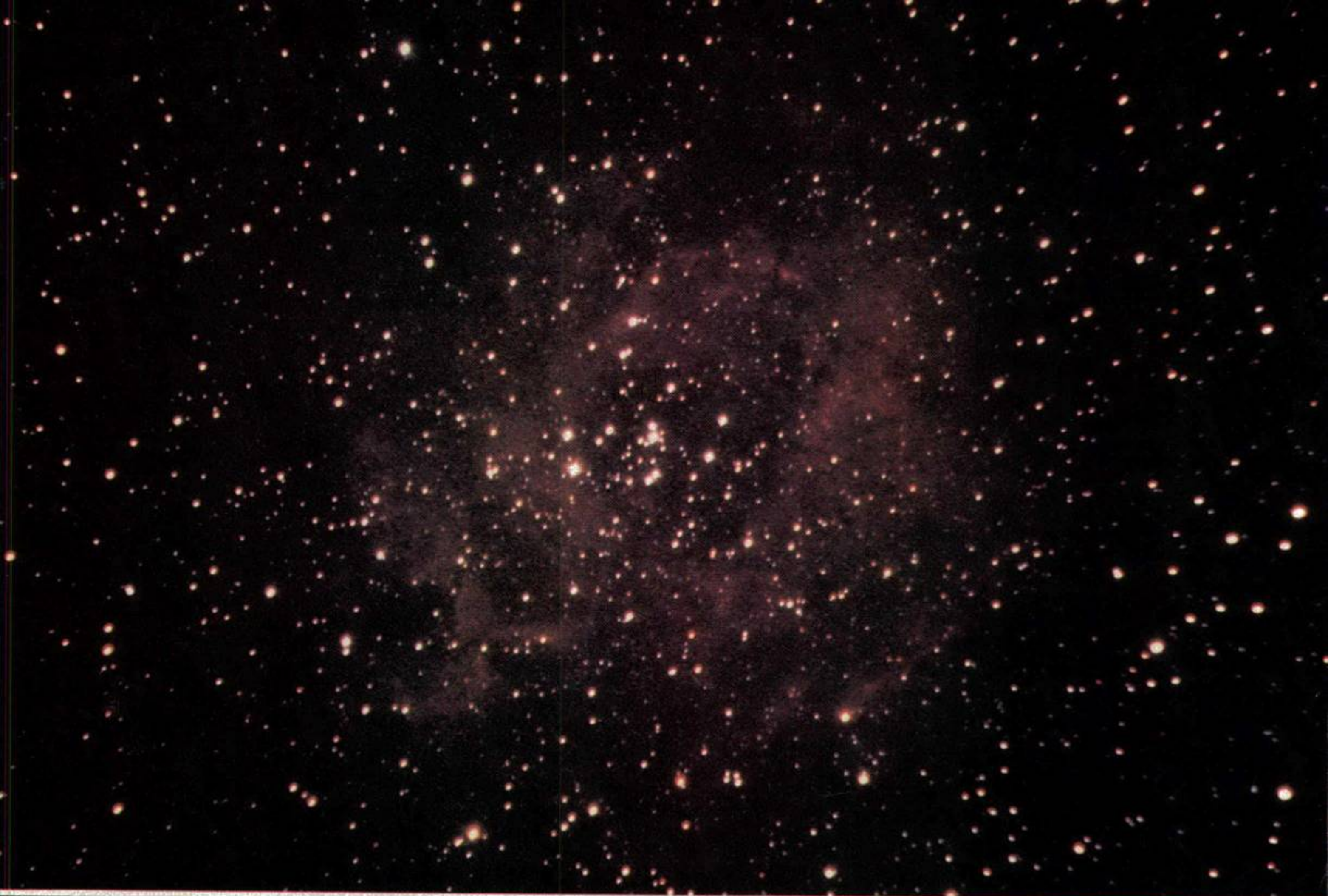
To make a system like this work, you need at least two cold camera film holders, and it's even better if you have three. If you build your own camera, there's no problem making several extra holders; if you buy one, you'll want the second glass plug. While one film holder is being exposed, the last one you shot is warming up, and the next holder is being "prepped-up" by our friend. You can happily spend the night sky shooting, taking pleasant breaks to alleviate the stiff neck you will get from guiding, and having none of the hassle that comes from doing the work of two people by yourself.

There is an exception: If your telescope is in the backyard and you can take pictures every night, you can prepare three or four films in advance, shoot them in order, and then take the rest of the night off; in other words, you can be your own partner. But if you have to take special trips for astrophotography, you'll find that using cold cameras isn't a one person job.

Although the steps for using each of the three types of cold cameras (the vacuum type, the dry air type, and the solid block type) are outlined on page 45, the general idea is the same for all of them. First, get the camera ready; second, cool it down to operating temperature; third, take the picture, and fourth, warm the camera and remove the film. From the chart, you'll see that what has to be done is very similar for all three types of cameras. Note also that your partner has a lot more work to do than you do if you are guiding the telescope. You'll appreciate why it takes two people to do cold camera astrophotography efficiently.

Since the outline is basically the same for all cold cameras (though details vary for each and every different cold camera), let's look at a few of the obvious problem areas and see how cold camera astrophotographers have handled them. It should be obvious from the pictures on these pages that when cold cameras do work, they work very well indeed.

Large image scale, good guiding, and a solid plug cold camera all contribute to the success of these photographs on the opposite page of the Horsehead nebula and Zeta Orionis (top), and the Pleiades star cluster and its reflection nebulosity (below). Each was shot on High Speed Ektachrome with a 12 inch f/4.5 Newtonian reflector and a homemade cold camera cooled with crushed dry ice. Photographs by Greg Griffith.



Above: The Rosette nebula glows red against a purplish-blue background sky in this 40 minute exposure. GAF 500 film was exposed in a solid plug type cold camera on a 12 inch f/4.5 telescope. The long focal length of this telescope gives a detailed image. Photograph by Greg Griffith. Opposite page: NGC-2264 shines blue, while the Cone nebula glows pale red in this exposure on High Speed Ektachrome through a vacuum cold camera on a 12 inch Newtonian. Photograph by Evered Kreimer.

1) Where can I get dry ice? You can get dry ice from a variety of sources — among them ice cream and frozen food distributors who use it to cool their trucks, and suppliers of industrial gases. Dry ice sublimes (evaporates) rapidly, even if you cool it in a freezer. Buy it in large enough quantities to last through the new moon period — 50 or 100 pounds at a time. Keep it in well insulated (thick styrofoam) coolers. You will need crushed dry ice for the cooling chamber; the easiest method is to place it in a heavy cloth bag or towel, and smash it with a hammer. Use gloves and handle it gingerly, because you can get frostbite in seconds if dry ice touches bare skin. For filling dry ice chambers, preload it in small, cotton cloth bags packed with dry ice; to fill a chamber, just stuff in a bag. In the dark, it then becomes much easier to use.

You can also obtain dry ice snow by venting a cylinder of liquid carbon dioxide into a condensation chamber. Edmund Scientific lists a moderately priced unit in their current catalog. Welding and industrial gas suppliers (check your Yellow Pages) sell suitable systems, but don't expect that they will know or even care what a cold camera is!

2) How can I focus my cold camera? If you insert the film holding part of the cold camera into the telescope with a sheet of finely ground glass in the film plane, you can do a tolerable job of focusing on a bright star. However, if you leave a 1/4 inch diameter circle of unground glass in the middle of a ground glass focuser, with a thin black strip painted or inked on it, you can focus by the *knife edge* method. Bring the star image into the clear portion of glass, and then place your eye close behind the glass; you'll see the mirror lit with starlight. If you now move the telescope to occult the star image with the black paint strip, the mirror will go dark; if the camera is properly focused, it will go out uniformly all over the mirror; if it's not in exact focus, you'll see a shadow move across the mirror.

For its cold camera, Celestron sells a "diopter correcting viewing assembly" — an eyepiece mounted in a Plexiglass block.

3) When I clean the cold camera, what should I clean? With vacuum cold cameras, the vacuum seal surfaces and the rubber "O" ring must be dust-free to give a good airtight seal. Of course, the camera window should be cleaned in all designs. Because the film is jammed tightly against the glass plug in a solid block design, utter cleanliness is essen-

Vacuum Cold Camera

Makeready

1. Check focus of telescope
2. Place cold camera in dark box
3. Remove dust from camera parts
4. Place film in camera
5. Attach cold back
6. Pump air from chamber (may take 30 minutes with a small pump)
7. Close vacuum valve

Cooldown

1. Place dry ice (or bag of dry ice) in cold chamber
2. Allow five minutes for cooling
3. Top up dry ice level
4. Cap camera window
5. Remove camera from dark box

Exposure

1. Acquire correct field and guide star with telescope
2. Cap telescope
3. Insert cold camera into telescope
4. Uncap telescope
5. Guide during exposure
6. Cap telescope
7. Remove cold camera from telescope
8. Cap cold camera window

Warmup

1. Place cold camera in dark box
2. Remove dry ice or ice bag
3. Allow camera to warm up
4. Admit dry air into vacuum chamber
5. Remove cold back
6. Remove film; place in storage box
7. Warm all camera parts
8. Dry all camera parts
9. Inspect for damage

Plug Cold Camera

Makeready

1. Check focus of telescope
2. Place cold camera in dark box
3. Remove dust from camera parts
4. Place film in camera
5. Attach cold back

Cooldown

1. Place dry ice (or bag of dry ice) in cold chamber
2. Allow two minutes for cooling
3. Top up dry ice level
4. Cap camera window
5. Remove camera from dark box

Exposure

1. Acquire correct field and guide star with telescope
2. Cap telescope
3. Insert cold camera into telescope
4. Uncap telescope
5. Guide during exposure
6. Cap telescope
7. Remove cold camera from telescope
8. Cap cold camera window

Warmup

1. Place cold camera in dark box
2. Remove dry ice or ice bag
3. Allow camera to warm up
4. Remove cold back
5. Remove film; place in storage box
6. Warm all camera parts
7. Dry all camera parts
8. Inspect for damage

Dry Air Cold Camera

Makeready

1. Check focus of telescope
2. Place cold camera in dark box
3. Remove dust from camera parts
4. Place film in camera
5. Attach cold back
6. Flush chamber with dry air or dry nitrogen (approximately 30 minutes with dry nitrogen is sufficient)
7. Seal chamber with black tape or plug

Cooldown

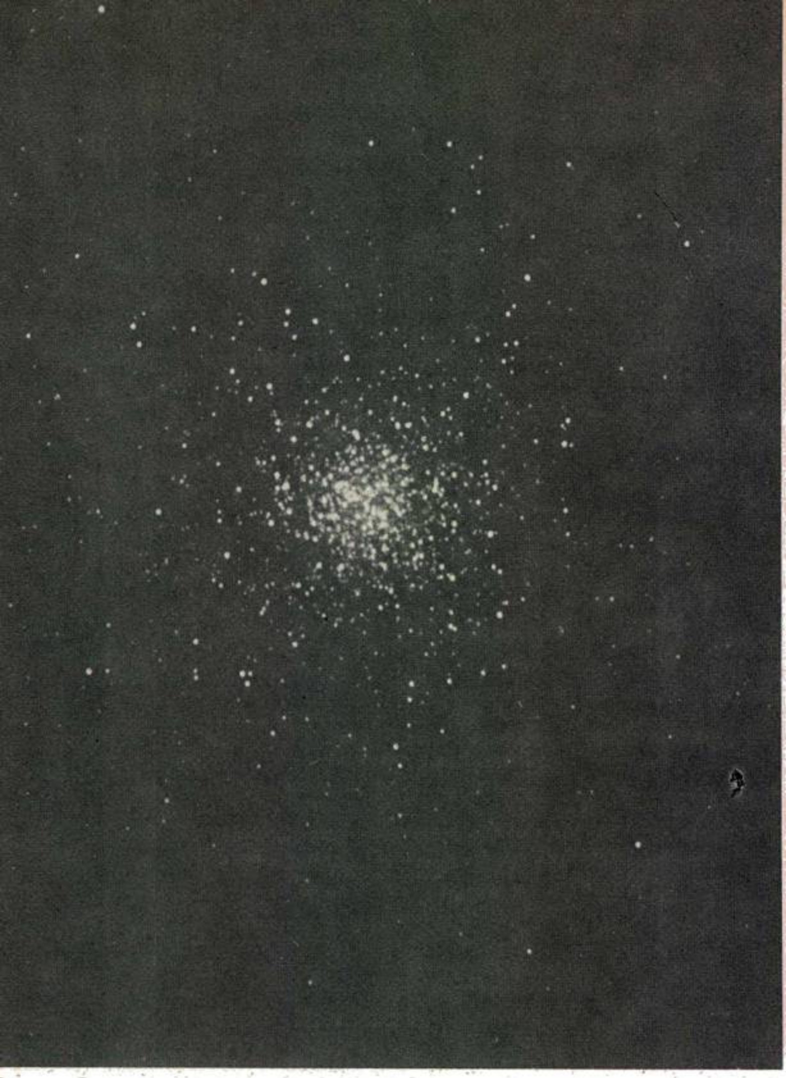
1. Place dry ice (or bag of dry ice) in cold chamber
2. Allow five minutes for cooling
3. Top up dry ice level
4. Cap camera window
5. Remove camera from dark box

Exposure

1. Acquire correct field and guide star with telescope
2. Cap telescope
3. Insert cold camera into telescope
4. Uncap telescope
5. Guide during exposure
6. Cap telescope
7. Remove cold camera from telescope
8. Cap cold camera window

Warmup

1. Place cold camera in dark box
2. Remove dry ice or ice bag
3. Allow camera to warm up
4. Remove cold back
5. Remove film; place in storage box
6. Warm all camera parts
7. Dry all camera parts
8. Inspect for damage



Opposite, top: High Speed Ektachrome was exposed for one hour in a vacuum cold camera on a 16 inch f/6 Newtonian reflector in this portrayal of the Cygnus Loop nebula. Opposite, bottom: The Dumbbell nebula (M-27) is vividly colored in this 30 minute exposure made with a vacuum cold camera. Photographs by Orien A. Ernest. Above: Identical 20 minute exposures without (left) and with (right) dry ice in the cooling chamber show the tremendous increase in Tri-X's speed obtained by cooling. Photographs by Leo C. Henzl Jr.

tial; any dust will show in silhouette against the nebula you are photographing. A blast of air and a soft brush will remove all but the most tenacious dust.

4) Where can I get a vacuum pump? You only need a small pump, and it need not create a very good vacuum; usually about 1/1,000 of an atmosphere is good enough. Scientific supply houses sell vacuum pumps, and their smallest is probably adequate to pull a frost-free vacuum. You can avoid vacuum pumps by using the dry air type cold camera; the best gas to use is dry nitrogen, which is available from industrial gas suppliers. Small cylinders for the gas are available for a few dollars, but rental on the cylinder itself is often fairly high. To use the gas bottles, you'll need a regulator, which may cost about $100.

5) The plug type cold camera sounds easiest to use; why bother with the other types at all? In general, the plug is not as good an insulator as the gas or vacuum, so the front of the plug will frost over in 30 minutes or so unless you use a small heater on the front of the plug. Also dust, marks and scratches are more likely to occur with the plug because the film is pressed against it. There's also some evidence that drying the film has some effect in reducing reciprocity failure: Both vacuum and dry air *do* dry the film. The plug type is easiest to use, however, and if you use Plexiglas for the plug, it is by far the easiest type to build yourself.

6) What films work best in cold cameras? Kodak's Tri-X Pan seems to be the champion: Its speed is increased about 10 times for a one hour exposure! High Speed Ektachrome and GAF 200 are two color films that respond quite well. In general, slow films do not respond well. Finally Kodak's spectroscopic emulsions are not improved; their reciprocity failure is largely removed in the manufacturing process.

7) Do I need a cold camera? If you can take good quality guided exposures up to 30 minutes long with your present equipment using black and white films, with good focus, guiding, and from a good quality observing site, you'll profit from a cold camera. Your astrophotography adventures could be extended into color emulsions or to the fine grain quality of Tri-X black and white, and you will gain real pleasure from the improvement in your results.

Warmer Nights, Dimmer Planets

Spring begins in the northern hemisphere on March 20 at 12:43 p.m. EST, when the sun reaches the vernal equinox (the point at which the sun crosses the equator northward in its apparent path around the sky). The planets, though still bright and easily spotted, are drawing away from Earth and gradually dimming as they go. By May, most of the bright planets will have left the evening sky.

Venus

Now rapidly approaching inferior conjunction (between Earth and the sun) and having passed greatest brilliancy at the end of February, Venus slowly becomes more difficult to observe during the month. It fades an entire magnitude — from -4.3 to -3.3 — and, as the planet approaches the sun, draws ever nearer to the western horizon at sunset. By the 31st, Venus will be only a few degrees above the horizon at dusk; inferior conjucntion is on April 6.

Although the other bright planets are moving farther away from Earth, Venus is an exception. Its distance decreases from 40 million miles (65 million kilometers) to only 27 million (43 million), while its apparent diameter grows from 38.9 to 58.3 seconds of arc — almost as large as Venus ever gets. By month's end, it will appear as an extremely thin crescent.

Jupiter

Hastening away from Earth, Jupiter moves eastward through the constellation Taurus during March. High in the sky at sundown, the giant planet sets shortly before midnight. Jupiter's magnitude is -1.7 for most of the month, as its distance from Earth increases from 485 million miles (780 million kilometers) to 525 million (844 million); its angular diameter shrinks from 35.2 to 32.5 seconds of arc. Note Jupiter's position about five degrees south of the Pleiades from the 20th to the 27th.

Saturn

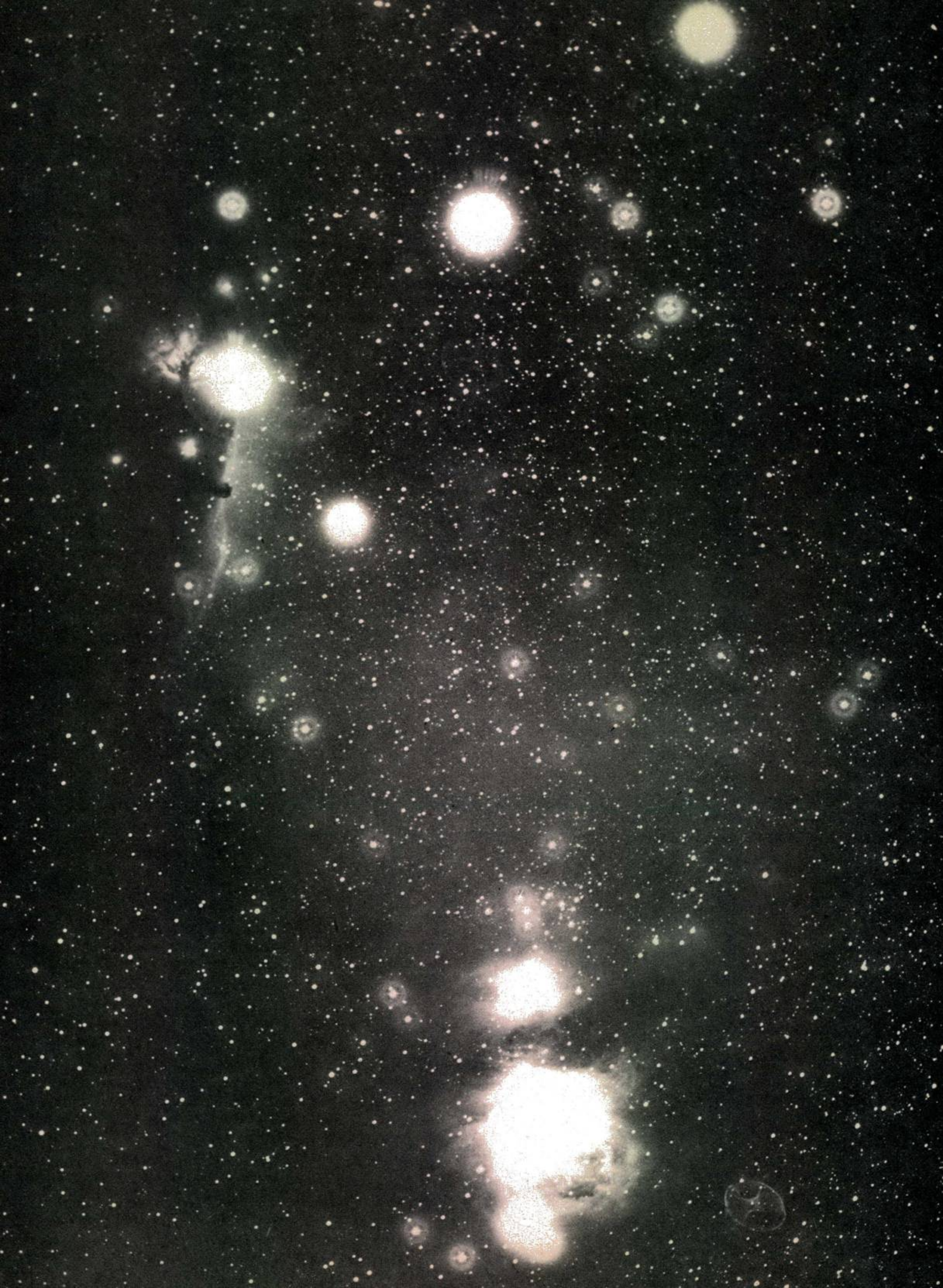
The ringed planet is still by far the brightest

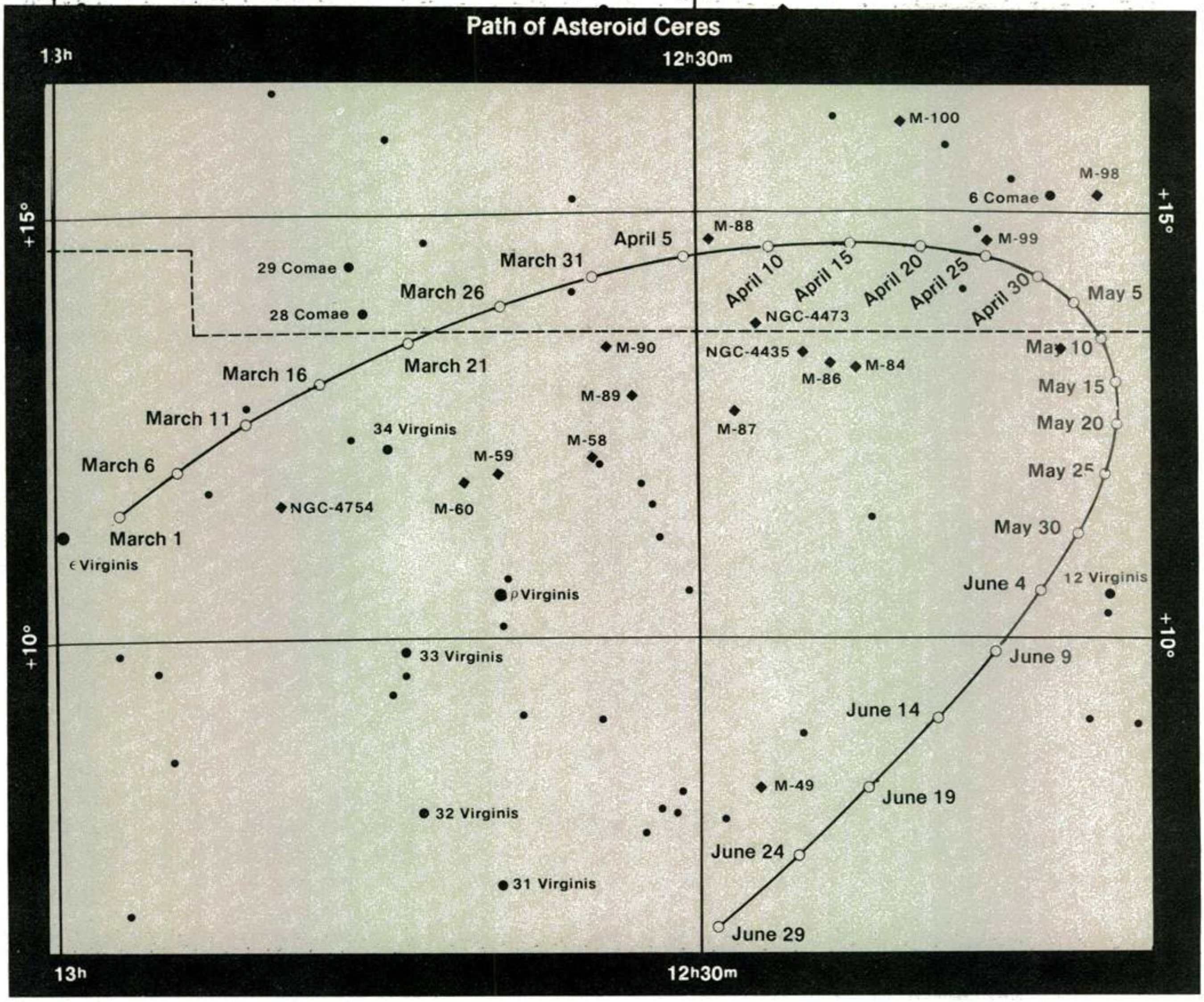
March Satellites of Jupiter
10:00 p.m. EST, 7:00 p.m. PST

1	32104	• • •● •	16	3024	• ●• •
2	30124	• ●• • •	17	31024	••● • •
3	1024	• ●• •	18	20134	• ●•• •
4	20413	• ●• • •	19	21034	•• ● ••
5	41203	•••● •	20	01243	●••••
6	40132	• ●•••	21	14302	•••●•
7	43120	• •••●	22	34201	••• ●•
8	4320	• • • ●	23	4310	• • •●
9	43012	• • ●••	24	43102	• • •● •
10	41302	• ••● •	25	42013	• • ●••
11	42013	• • ●• •	26	42103	• • •● •
12	14203	••• ● •	27	40123	• ●•••
13	04123	●•• ••	28	4102	• • ●•
14	1304	••● •	29	32104	•• •● •
15	32014	•• ● •	30	31204	• ••● •
			31	3104	• • ● •

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 11 p.m. (EST) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1=Io; 2=Europa; 3=Ganymede; 4=Callisto, and 0= Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

The central region of Orion is rich in nebulae. Most prominent, of course, is M-42, seen at the bottom of this photograph. This is the densest concentration of nebulosity that enshrouds this entire area. An intervening dark cloud of dust produces the distinctive Horsehead nebula just south of Zeta Orionis. A "ghost" image to the right of M-42 is the result of the optical system used. This 20 minute exposure on SO-410 film was taken with a 5.5 inch Schmidt camera. Photograph by Christopher Bowland.




Path of Asteroid Ceres
13h
12h30m
+15°
+10°
March 1
March 6
March 11
March 16
March 21
March 26
March 31
April 5
April 10
April 15
April 20
April 25
April 30
May 5
May 10
May 15
May 20
May 25
May 30
June 4
June 9
June 14
June 19
June 24
June 29
ε Virginis
29 Comae
28 Comae
34 Virginis
NGC-4754
M-59
M-60
M-58
M-89
M-90
ρ Virginis
33 Virginis
32 Virginis
31 Virginis
M-88
NGC-4473
NGC-4435
M-86
M-84
M-87
M-49
M-100
M-98
6 Comae
M-99
12 Virginis

This map traces the path of the asteroid Ceres through the constellations Virgo and Coma Berenices from March through June 1977. The asteroid is at opposition on March 24, after which it makes a loop through the region known as the Realm of the Galaxies (individual galaxies are shown as diamonds on this map). Note especially Ceres' close approaches to M-88 on April 6, and to M-99 on April 25. At magnitude 6.5 on its opposition date, Ceres is about as bright as it ever becomes.

object in the dim constellation Cancer. Its magnitude decreases slightly in March from +0.2 to +0.3, as the planet's distance increases from 768 million (1,235 million) to 800 million miles (1,287 million kilometers). Saturn is well placed for observing, located high in the sky for most of the night and setting just before sunrise.

Uranus

Located in Libra, Uranus moves retrograde a few degrees east of Alpha Librae throughout the month. The planet is of special interest around March 10, when it will occult the ninth magnitude star SAO 158687. This occultation will be visible only in parts of Africa, Asia and Australia, but observers elsewhere will be able to see Uranus' close approach to the star. Uranus' magnitude is 5.7.

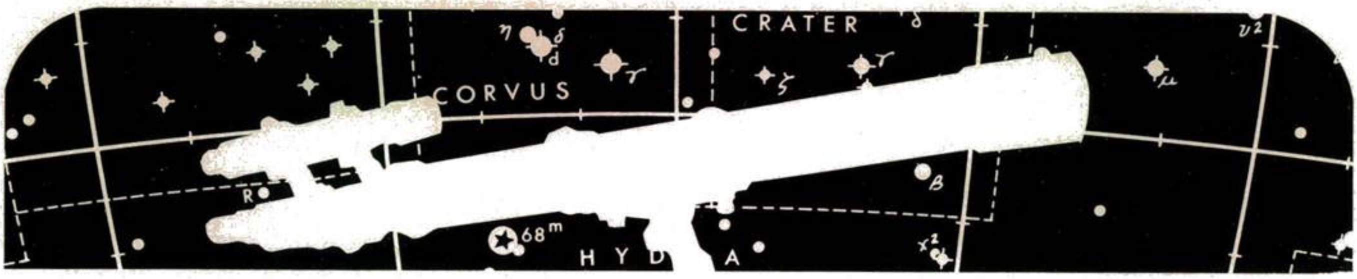
Mercury, Mars

These two planets are both too close to the sun for easy observation during March, although Mars will gradually become visible in the morning sky and will be easily spotted by the end of April.

Asteroids

Ceres, the largest of the asteroids, comes to opposition on March 24; on that date it will be located almost exactly on the border separating Virgo and Coma Berenices. In the months to come, Ceres will make a retrograde loop through the Realm of the Galaxies, closely approaching several of those in the Messier catalog. See the map on this page for Ceres' location during the spring months.

Another notable asteroid event occurs during the first week of March, when asteroid 44 Nysa will creep slowly northwestward through the stars of the Beehive (M-44) in Cancer. As indicated in the chart on page 11 of the June 1976 issue, Nysa is one of the most highly reflective asteroids, with an albedo of 45 percent. It will be a ninth magnitude object in early March. Can one of our enterprising astrophotographer/readers obtain pictures of Nysa's path through the Beehive?



EQUIPMENT ATLAS

Binoculars for Stargazing
Part 2

by
A. John Martellaro Jr.

A glimpse of the dark night sky through binoculars will leave just about anyone awestruck: The Milky Way stretched out like millions of tiny diamonds strewn onto black velvet or the wispy, milky disk of the Andromeda galaxy is a sight not to be forgotten. Even so, with modern optical techniques and recent advances in binocular design, there is a whole new family of binoculars which can make the heavens even more accessible and breathtaking. Unfortunately, using the wrong binocular for astronomical use can cause you to lose out on some of this splendor. How do you pick the best astronomical binocular? While "Binoculars for Stargazing" (ASTRONOMY, January 1976) presented a basic introduction to the terminology of binoculars, this article will tell you what you need to know, in more detail, about selecting the right astronomical binoculars.

One of the more important things to consider about a pair of astronomical binoculars is how much they weigh: You won't be spending much time viewing if you can't be comfortable with your equipment! And when not in use, a heavy instrument can be a nuisance with the straps biting uncomfortably into your neck, and the glasses swaying back and forth banging into other things.

On the other hand, if you want the best pair of astronomical binoculars you may have to sacrifice some comfort. A good instrument should gather a lot of light — but big lenses will mean a big, heavy frame and prisms. Secondly, they should have a wide usable field of view to make things easier to find — necessitating large eyepiece lenses and prisms, and accordingly a lot of weight.

It's not always true that the observer is using all the light available from the binoculars. To understand this, we must remember that the *exit pupil* is the diameter of the cylinder of light that comes out of the eyepiece. It is determined by dividing the diameter of the objective lens (the second number in the conventional description of binoculars) by the magnification (the first number). For example, a pair of 8x40s has a 40/8 =5mm exit pupil. But if the eye's pupil is less than the exit pupil, you can use only part of the objective lenses, according to the following equation:

$$\boxed{\text{diameter } \textit{used} = \text{actual diameter} \left(\frac{\text{eye pupil diameter}}{\text{exit pupil diameter}}\right)}$$

For example, in the daytime the pupil of your eye will close to about 2mm, so only the central 14mm of a pair of 7x50 objective lenses are used:

$$\boxed{\text{14mm used} = \text{50mm actual diameter} \left(\frac{\text{2mm eye pupil}}{\text{7mm exit pupil}}\right)}$$

This is one reason why it is nearly impossible for a buyer to comparison-test binoculars in daylight when intended for nighttime use. Assuming a focal length of 175mm, the objective lens is working at f/12.5, and virtually any optical system performs well at that f-ratio. But if the eye's pupil is open as far as it will go, it will be just about 7mm in diameter for an adult.

A pair of 7x50s which, only under the best conditions, exploit their 7mm exit pupil will be expensive, arm busting binoculars which can weigh three pounds (1,400 grams) — or more if they are the wide field type. Only the most experienced observer can detect the difference between a pair of 7x50s and 7x35s (which generally weigh half as much).

Wide Field Binoculars

Wide field binoculars use eyepieces of a different design, having larger diameter lenses. The lens in the eyepiece closest to the eye is called, appropriately enough, the *eyelens*. Typical regular field eyepieces have an eyelens about 12mm in diameter; a wide field's will be perhaps 25mm in diameter. Since the wide field eyepieces have more glass and require larger cones of light (meaning bigger prisms), the binoculars will weigh and cost more. The light path through the larger prisms is longer, so the barrels are shorter. The "stubby" design with larger eyelenses is the "giveaway" for wide field design.

Wide field eyepieces have a large apparent field. This is the apparent size, in degrees, of the circle of light seen when you look into the eyepiece. Inexpensive field glasses have a very small apparent field (it's like looking down a narrow tunnel). Normal field eyepieces are the Kellner type with an apparent field of about 50 degrees,yielding a pleasing circle of light. Wide fields usually use a variation of the Erfle design with an apparent field of 65 to 70 degrees, making it almost impossible to see any dark around the outside of the image — a kind of panoramic effect.

Many people today wear glasses — either corrective lenses, or perhaps sunglasses when using binoculars for daytime events. Wearing any kind of eyeglasses forces the viewer to have his eyes farther away from the eyelens, which can cause a problem.

In optical design, the larger the apparent field for a given eyelens diameter, the shorter the distance behind the eyelens where the image with the widest field is formed. This distance is called the *eye relief*. The result of this is that only if you don't wear glasses can you ever get close enough to the eyelens to see the entire field of a wide field eyepiece! If you wear glasses, you'll be forced to be farther back, thus seeing a reduced field of view. (If you are farsighted you can take your glasses off and refocus; however, those who are wearing sunglasses or who are nearsighted will have to leave their glasses on.) Hence, all that extra weight and expense for wide field binoculars has gone out the window.

Consider the specifications for two binoculars which illustrate this point: The first has an apparent field of 56 degrees and an eye relief of 20mm, allowing the full 56 degree field to be seen with glasses on; the second pair has an apparent field of 65 degrees, but the eye relief is only 9mm. The result is that with the second pair, you can only see about 25 degrees of the field. Wide field types are supposed to have larger eyelenses to increase the eye relief, but many do not as a cost (or weight) cutting measure. And remember, just because a pair of wide field binoculars has rubber eyecups which fold down does not mean that they are especially designed for eyeglass wearers. The only way to be sure is to try them out.

On the other hand, if you do not wear glasses, wide field types are excellent and well worth the extra expense if you don't mind the added weight — typically an extra nine ounces (250 grams). One of the advantages of wide field types is their ability to help you find moving objects quickly, such as satellites or aircraft. Even though the image quality is poor near the edge of the field — because the light is bent more sharply there — you can spot the movement with peripheral vision and quickly move the object to the center of the field. Of course, wide field binoculars also give you a more pleasing wide field view of the sky, producing a feeling of being right out there in space.

Roof Prism Binoculars

A little more than a decade ago, the Germans invented a revolutionary new binocular using *roof prisms* instead of the conventional *porro prisms*. Although they appear to be cheap field glasses because of their "H" design, they are in fact sophisticated prism binoculars, typically weighing half that of their porro prism counterparts. Leitz introduced the "Trinovid" and Zeiss, the "Dialyt". For several years they were the only roof prism binoculars available; today they cost a small fortune (around $500). A few years ago, however, several domestic roof prism brands (actually made in Japan) became available: the Swift "Trilyte", the Jason/Empire "Minitron", and the Bushnell "Custom Compact". All are easily within the budget of most astronomy enthusiasts, costing less than $100 at discount stores. Or, special "deals" can often be found by looking around in magazines for specialty sports or camera stores which carry binoculars.

These binoculars are by far the best for stargazing. For example, a pair of Leitz 7x24B night glasses — which weigh a mere 24 ounces (650 grams) — can comfortably be held all night and do essentially the same job as a pair of 7x50s which weigh twice as much. (The "B" suffix means that they are especially designed for eyeglass wearers — "Brille" in German — allowing the entire field to be seen.)

Compact roof prisms are more easily secured and less likely to slip out of alignment. Also, most roof prism designs have *internal focusing* which allows them to be sealed against moisture and dust. While the three dimensional effect is lost slightly in daytime use because the objective lenses are closer together, this is of no consequence for celestial objects which are very distant. In fact, their slimmer design makes them easier to hold and store: A typical pair of 7x35s is about five inches (125mm) square, not much more than 1-3/8 inches (35mm) thick, and weighs only 17 ounces (500 grams). Generally, they do not come in the 7x50 size, since that defeats the purpose of their being small and compact. Zeiss does make an 8x56 Dialyt which sells for about $510 — out of the price range of many observers.

Among the reasons why the German brands are so expensive are: multilayer coatings on the lenses; air spaced objectives, providing four surfaces for

Binocular Types Compared

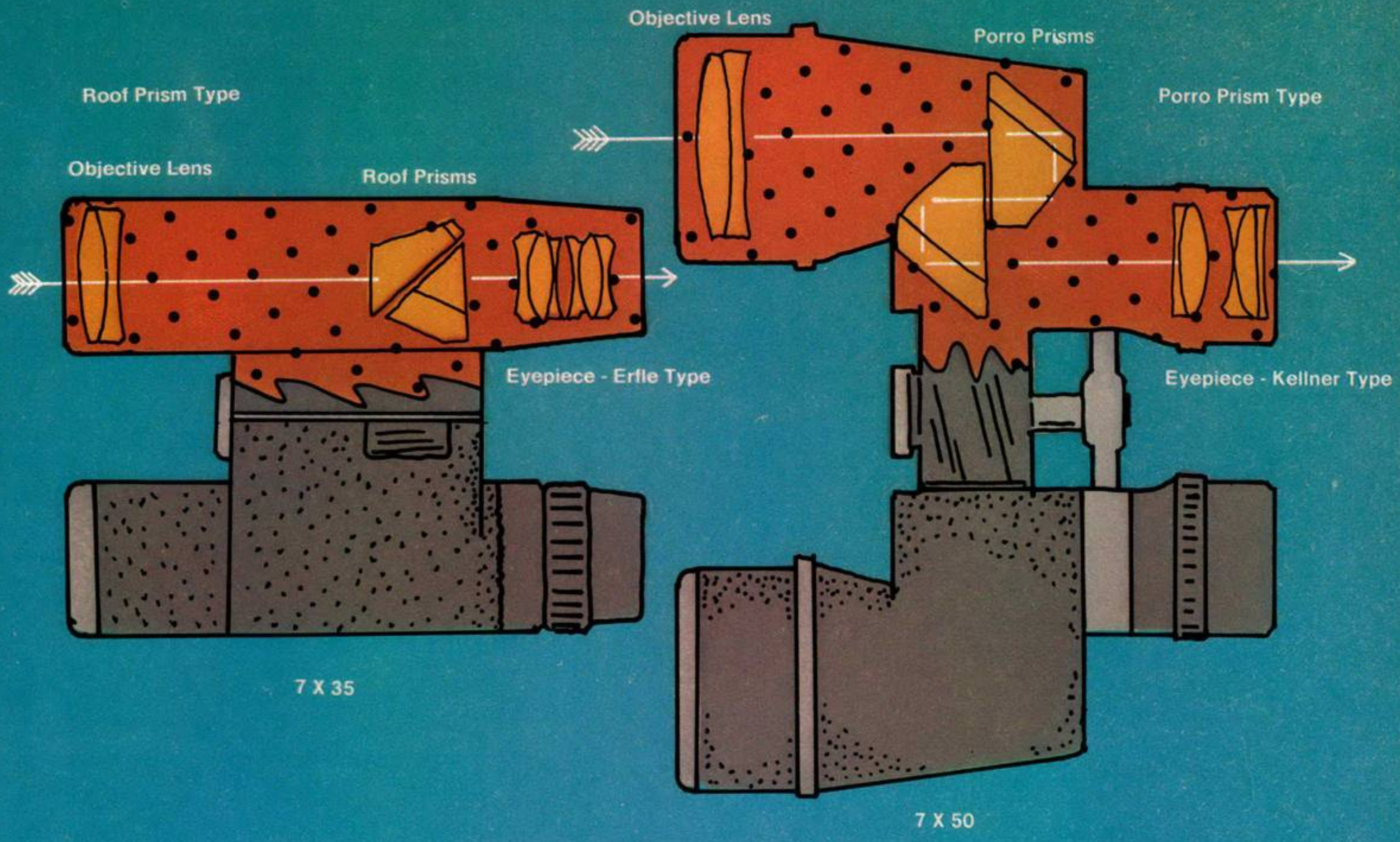


Diagram by Mark Paternostro

the correction of aberrations instead of three; the right eye diopter adjustment is often internal; construction quality is much higher; the optics are about the best available on planet Earth, and — of course — import duties.

Finally, since these roof prism brands are slightly more sophisticated and expensive than porro prism types, virtually any brand will be of good quality and can be bought with confidence by mail order. This is not recommended with conventional types costing under $40.

Buying Hints

The real field of a binocular is either given as linear feet visible at 1,000 yards (or meters at 1,000 meters), in degrees, or both. Don't confuse this with magnification. It means that if you were at sea and the glasses had specifications of 376 feet at 1,000 yards, a ship 1,000 yards away and 376 feet long would just fill the field of view. To convert to degrees, remember that about 52.4 feet at 1,000 yards (17.5 meters at 1,000 meters) is one degree. Hence, a specification of 376 feet/1,000 yards means a 376/52.4 =7.2 degree real field. Two stars in the sky, seven degrees apart, could just be seen in the same field. As the magnification goes up (for a given eyepiece design), the real field decreases. (This effect is most pronounced on zoom binoculars.)

The real field is found by dividing the apparent field in degrees by the magnification. For example, a 63 degree apparent field and a magnification of seven will produce a 63/7 = 9 degree real field. Usually, the apparent field is not given, but the real field is. Knowing this, it is possible to determine whether a binocular has a wide field eyepiece. (Wide field usually means anything over 60 degrees.) Suppose the catalog for a pair of 10x50s says 250 feet/1,000 yards. The real field is 250/52.4 =4.8 degrees, and 4.8 degrees times 10 power yields a 48 degree apparent field — meaning they are normal field binoculars. It should be clear by now that a pair of wide field binoculars can have a very small real field if the magnification is high.

If you are buying your binoculars in a store which has fluorescent lights, point the objective lenses upward and peer over into them until you see the multiple reflections of the light fixture in the objective lens and prism. All the reflections should be bluish. Any white images indicate a surface which has not been coated with a quarter wavelength (of light) thickness of magnesium fluoride (MgF_2). This dielectric coating reduces the reflection at the glass surface from four percent for uncoated glass to about 1.5 percent. The color of the magnesium fluoride is determined by its thickness; if you see an amber colored reflection, this is all right too. Some inexpensive binoculars have only the outside lenses coated leaving the internal lenses uncoated. This will result in light loss, ghosts,

Binocular Math

Relative Light Efficiency (RLE) is a term very often used to describe the relative amount of light passing through an optical system. The catch here is that it refers only to a situation in which the human eye is fully accommodated to (that is, the same size as, or larger than) the exit pupil of the system. The definition of RLE is:

$$\mathrm{RLE} = 2T^{n}(D/M)^2$$

where T is the fraction of light transmitted at each air-glass surface, n (an exponent) is the number of these surfaces, D is the objective diameter in millimeters, and M is the magnification. Here we are assuming T is the same for all surfaces. For example, a pair of 7x35s with 10 air-glass surfaces coated with MgF_2 ($T = 0.985$) will have an RLE of:

$$2(0.985)^{10}(35/7)^2 = 43.$$

Such an instrument passes half the light under the same conditions as one with an RLE of 86. The higher the RLE, the better the system is for some astronomical purposes. In the bright daylight, however, with the eye's pupil stopped way down, the RLE of all binoculars is about the same since the eye cannot utilize the full exit pupil. This is a point often neglected by binocular manufacturers.

The above refers to "extended objects" — objects which appear to have a finite size. Notice that the important factor in the RLE is $(D/M)^2$ or D^2/M^2. The situation is quite different for point sources like stars, because magnification simply doesn't matter! For point sources, the controlling factor is simply D^2. For seeing faint stars, what is important is the *ratio* of the star brightness to the sky background which is an extended source. This ratio is D^2 divided by D^2/M^2 or M^2. As the magnification goes up, the contrast between the sky background and the stars is increased. For example, a pair of 10 power binoculars will have twice the contrast as a pair of 7 power, since comparing the term M^2 for both we get $10^2/7^2 = 2$.

In summary, if you are looking for faint stars or other starlike objects, use a somewhat higher magnification. But if you plan to look primarily at extended sources like nebulae, galaxies and planets, go for the largest exit pupil (up to 7mm) you can get.

and loss of contrast. The more expensive German types use multilayer coatings which reduce the reflection to well under one percent at each surface; their images are brilliant, with high contrast.

Choosing and Testing Binoculars

The ideal test of a pair of binoculars is the planet Jupiter. Choose a time when Jupiter is high in the sky. All of its light should be within a small, easily discernable circle of light — the disk of Jupiter. If almost all the light will not focus down into a circle without flares, or you detect color fringes around the image (chromatic aberration), the binocular's quality is not what is needed for astronomy — although they may be great at football games. Jupiter's moons should be sharp pinpoints of light, and the secondary reflections of Jupiter (ghosts) should not be objectionable. Finally, move Jupiter to the edge of the field. Even the best binoculars will let the perfect image of the planet smear slightly into an oblong shape, and the moons will become little comets in shape. But if the image completely goes to pieces closer in than 75 percent out to the edge, you may want to test another pair. If Jupiter is not available, a bright double star can be used.

Most observers are interested in both stars and faint extended objects, so some compromise is in order. For stars alone, 10x50s are excellent; however, a pair of 10x40 roof prism types would weigh about half as much. For faint extended objects with perfect seeing conditions, 7x50s are probably a good choice, but 7x35s are sufficient in average conditions. You must decide whether you can really use a 7mm exit pupil. Beware of monstrous 8x56s or 20x120s *unless you are an experienced observer and have a special purpose in mind.* Once you have decided on your needs, try to find a roof prism type with the proper specifications. If you want to observe for extended periods of time in less than ideal conditions (and daytime too), the 7x35 roof prism binoculars for under $100 are the best choice. But if you're on a limited budget, good quality 7x35 porro prism binoculars are available for about $50. For the purist who wants the best, the Leitz 7x42B or the Zeiss 8x56B are excellent choices.

Remember that you cannot effectively test binoculars in the daytime, and that most reputable stores let you return goods if they are returned in excellent condition. But check with the clerk *first* (before you have paid), and if necessary insist that "Sale Subject to Testing on Stars" appear on your receipt. If you wear glasses and want to see the entire field, only binoculars with a "B" suffix will allow it. And when in doubt, get the lightest pair with at least a 5mm exit pupil.

A. John Martellaro holds degrees in astrophysics and physics, and is currently studying for his doctorate in astronomy at New Mexico State University. He previously served as a captain in the Air Force Space Tracking System.

ASTRO-NEWS

Latest News From the World of Astronomy

Update on Martian Life

The question of whether there is life on Mars is still relatively unsettled. More experiments have been performed by the Viking biology packages, and more soil samples have been processed. If a definite answer isn't found, it may be that the experiments were just too limited in their design.

The outline of the Viking biology experiments and their early results were described in the January 1977 issue of ASTRONOMY. However, there was some question of whether the interaction of the ultraviolet component of sunlight with Martian soil particles could be responsible for a peculiar soil chemistry that would account for the results. To investigate this question, the Viking team used the sampling arm on Lander 2 to push aside a rock and obtain a soil sample from beneath it, where it had been protected from the light at least for thousands of years. The results were intriguing.

For both Landers 1 and 2, the *gas exchange experiment* showed that soil exposed to sunlight would release oxygen gas when moistened. It was this discovery that led the Viking team to suggest that the soil contained peroxides, superoxides or ozonides — perhaps as a result of ultraviolet illumination. The under-rock soil sample, however, also released oxygen gas when moistened. This suggests that if the response is due to soil compounds produced by ultraviolet light, the compounds are stable, since they had to have formed before the rock fell or rolled into place. It also suggests that the response is not likely to reflect the activities of photosynthetic organisms, unless their oxygen-containing products are stable or they themselves can take shelter under rocks.

For Lander 1, the *pyrolytic release experiment* showed that soil exposed to radioactive carbon dioxide, carbon monoxide, and light would apparently incorporate the carbon dioxide and monoxide into organic compounds. The incorporation would not occur if the soil was first sterilized by heating to 350 degrees Fahrenheit (175 degrees Centigrade). Lander 2's runs of the pyrolytic release experiment were not duplicates of Lander 1's, as they were not performed in light. Lander 2's first run was performed in the dark, and its second was performed in the dark with moisture added. Both runs failed to show much assimilation of carbon, though the first did show some. This implies that the assimilation process, whether due to soil chemistry or life, requires light for its full expression and is inhibited by water. When the under-rock sample was tested, it was processed in the dark and without water, so it is not surprising that it showed little or no carbon assimilation. The numbers did, however, suggest less carbon assimilation than was seen in the dark-tested surface sample, which may imply the existence of less of the responsible soil compounds or fewer organisms out of the light.

The most interesting results so far have come from the *label release experiment*. A soil sample is exposed to water and nutrients (labeled with radioactive carbon), in which release of radioactive carbon-containing gases is monitored. Lander 1 demonstrated that such gases were indeed released and that the agent responsible — organic or inorganic — was inactivated when the soil was sterilized by heating to 320 degrees Fahrenheit (160 degrees Centigrade) for three hours. It also showed that the agent remained active when heated to 65 degrees Fahrenheit (18 degrees Centigrade), as happened during one run of the experiment. Lander 2, however, showed that the agent could be inactivated as completely by a temperature of 120 degrees Fahrenheit (50 degrees Centigrade) as by one of 320 degrees Fahrenheit. This is clearly suggestive of life, since soil chemistry can be presumed not to be so sensitive to small temperature differences, while Martian organisms would be adapted to very low temperatures and vulnerable to what we regard as moderate temperatures. To them, 65 degrees Fahrenheit may be the equivalent of a hot summer day (110 degrees Fahrenheit, or 43 degrees Centigrade) to us, while 120 degrees Fahrenheit may be quite beyond their survival limit.

Lander 2's label release experiment on the under-rock soil sample gave results nearly identical to the ones obtained earlier on unsterilized soil samples. The activity this experiment measures is therefore not dependent on recent exposure to light, and the agent responsible is stable for long periods. This may imply the existence of nonphotosynthesizers — animal-like organisms that can take shelter out of the light, perhaps moving from their shelters to obtain food and oxygen from the photosynthesizing organisms in the exposed soil.

The pyrolytic release results do suggest that Martian photosynthesizers (if any) are more numerous in exposed soil; the results from the label release experiment are consistent with a division of Martian life forms into nonmotile photosynthesizers and motile nonphotosynthesizers; the gas exchange results suggest a mechanism for their interaction which needs to be modified only slightly (over that given in the January issue) to account for the release of oxygen from the moistened under-rock soil sample. The nonphotosynthesizers may store oxygen themselves, releasing it when exposed to water by other nonphotosynthesizers, or predators. After all, oxygen on Mars must be as precious and fought-over a commodity as water and food are on Earth.

Viking scientists are trying hard to find nonbiological explanations for the Viking results, but so far without much success. Duplicates of Martian soil are being prepared, exposed to simulated Martian conditions, and tested for their abilities to replicate the experimental results. A chemical explanation may emerge within the next few months.

Scientists Explain Evolution, Formation of Ring Galaxies

Picture a disk of stars and dust 100,000 light-years across — a galaxy — moving through space. An "intruder galaxy" approaches the flat of the disk and pierces through it, ripping matter from the center and leaving behind a great ring of gases and stars.

This is how the rare and little-known celestial forms called "ring galaxies" are made, according to scientists Edward A. Spiegel, professor of astronomy at Columbia University, and his former student, John C. Theys, now assistant professor of astronomy at the State University of New York in Stony Brook.

Since the first ring galaxies were observed 20 years ago, 12 have been discovered in the universe, but their origin and evolution has remained mysterious. Some scientists guessed that the rings were formed when galaxies passed through hypothetical clouds of gases, causing the clouds to congeal into rings. But since clouds capable of such action have never been observed, scientists sought a more plausible explanation. Spiegel and Theys have concluded that the rings are formed by great collisions between galaxies lasting 100 million years or more. The collisions, they report, stir dust and gases in the disk into an outward expanding ring of old and newborn stars. As the intruder passes through, it may take a sizable portion of the disk galaxy's matter with it.

"These objects invite attention, not only because they look unusual but also because . . . they provide the possibility of observing dynamically significant galactic activity," the scientists said. They reported that the rings' activity resembles that of early stages of galactic development. Ring galaxies have formed at different times in widely scattered parts of the universe.

The rings have been observed and photographed by astronomers around the world, particularly at Hale Observatory in Palomar Mountain, Calif., and Kitt Peak National Observatory in Tucson, Ariz.

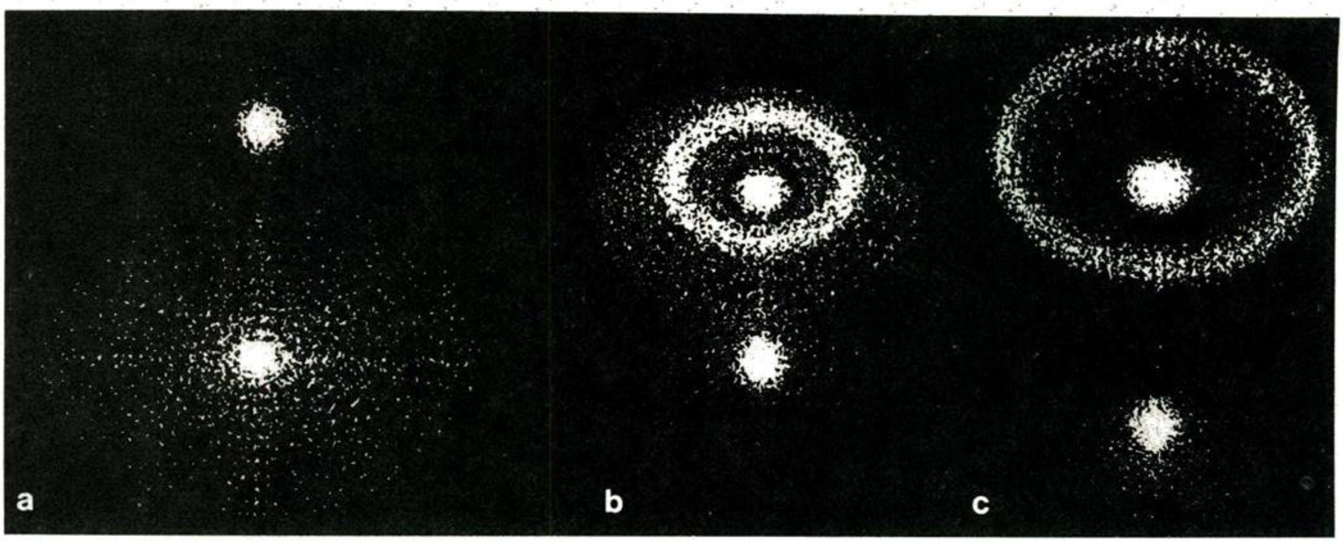
All true ring galaxies are characterized by "crisp, well-defined rings". Spiegel and Theys have classified three types: those with empty interiors, those with a single cluster or nucleus of stars off-center inside the ring, and those with a "knot" or bulge of densely packed matter in the ring itself. The differences, they report, reflect the angle at which the "parent" galaxies collided.

In oblique-angle collisions, a nucleus of matter displaced from the disk galaxy by the intruder is deposited either off-center inside the ring, or as a knot of matter in the ring itself. But in a perpendicular, dead-center hit, the intruder merges with matter torn from the disk and passes through, leaving an empty ring of stars in its wake.

The remnant of the intruder, together with matter displaced from the disk, combine to form what Spiegel and Theys identify as "companions" near each ring — galaxies of various disklike shapes and sizes. The distance between a ring and its companion is a clue to the ring's age: The greater the distance separating them, the older the ring. According to this measure, ring galaxies are 100 million to 200 million years old.

"Beads" or dense clusters of stars embedded in some rings provide another check on the galxies' ages. Because rings are gravitationally unstable, the ring begins collapsing into islands of smaller galaxies as a galaxy revolves. "Beading" marks the first stage in this process and begins, according to computer simulations, as

RING *continued on page 57*



The creation of a rare ring galaxy, as newly conceived in this computer simulation by astronomers from Columbia University and the State University of New York at Stony Brook, occurs when an "intruder galaxy" approaches the flat of a disk galaxy (a) and pierces it, displacing matter from the center (b). The collision stirs dust and gases within the disk into an outward expanding ring of stars (c). Passing through, the intruder forms a "companion galaxy" near the ring at left, and in this case leaves a nucleus of material in the center of the ring. Columbia University/SUNY simulation.

Theory Says Moon Formed From Meteorites

A geochemist at the University of Chicago's Enrico Fermi Institute has released a study of lunar rocks, billions of years old, which gives evidence that the moon was most likely formed from smaller objects.

Dr. Robert N. Clayton told a meeting of the American Association for the Advancement of Science that "we have new information to support the theory that the moon and Earth grew from smaller objects, from 10 to 100 miles in diameter."

"There are different kinds of meteorites formed in different parts of the solar system," Clayton explained. "What we've done is to determine which ones were more closely related to the origin of the moon. By measuring the isotopes (atoms of oxygen in the rocks), we find that the moon was formed from material which closely resembles a class of meteorites known as achondrites, formed by freezing after a melt in a temperature of 1,900 degrees Fahrenheit."

According to Clayton, "It is highly unlikely now that the moon was captured by Earth after being completely formed in some other region of the solar system. A long time ago Earth and the moon were bombarded with rocks. On Earth they withered away because of the elements which were not present on the moon. By studying the rocks that the astronauts brought back, we can place the age of the moon at between 4 and 4.5 billion years."

Clayton believes that Earth and the moon grew simultaneously by the smashing together of meteorites and miniplanets 10 to 100 miles in diameter. Earth could be older, but not by much; the maximum age difference is 100 million years. Earth's attraction (the force that attracts meteorites today) pulled in the achondrites.

Clayton believes that the smashing together occurred at essentially the same time. "Earth got a head start. The process began with small meteorites smashing together and then grew.

"There is evidence that the back side of the moon is different," Clayton said. "There is a different rock history on the far side; the crust is thicker. We know it's different, but we don't know why.

"The moon keeps one face toward Earth all the time," he added. "We don't know how long it's been locked into that. When you consider the time scale of the rock bombardment on the moon, we can assume that large objects were striking Earth at the same time. This record has been preserved on the moon but it disappeared long ago on Earth. The heavy rock bombardment on the moon ended approximately 3.9 billion years ago. The process became much slower after that. This corresponds with the oldest rocks on Earth."

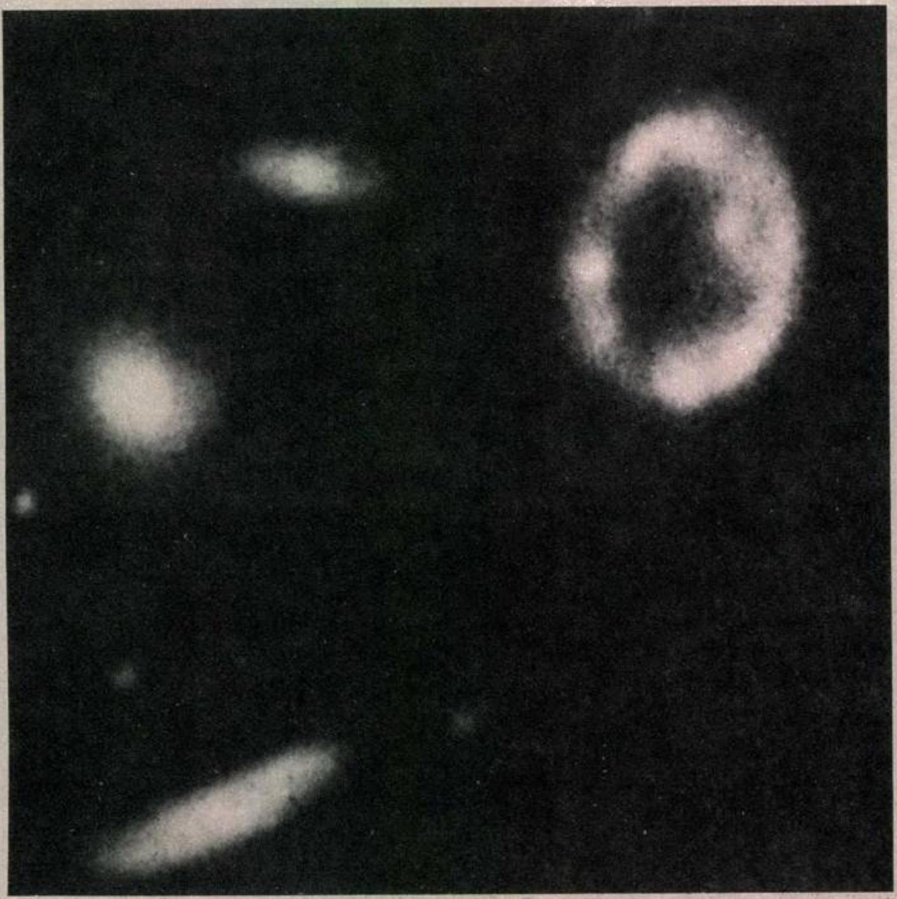
Presently there are no plans for further manned missions to the moon. Clayton feels that future unmanned orbiting will be in a polar, vertical orbit rather than the horizontal orbit previously used. The vertical orbit should enable scientists to conduct chemical and geophysical studies to determine sights for future manned or unmanned lunar landings.

RING *continued from page 56*

soon as a ring takes shape. After several galactic revolutions (lasting 500 to 600 million years), a ring dissolves into a swarm of small galaxies.

Subsequent stages in the galaxies' evolution are uncertain, though simulations indicate that the smaller galaxies collide and eventually merge. Each collision adds matter to the growing core until over "some billion years", the scientists estimate, most of the matter has been concentrated into a dense ball of gases and stars.

Spiegel and Theys believe these compact objects could evolve into radio-wave-emitting "active" galaxies. In 1975, astronomers from the University of Texas detected what appeared to be a Seyfert nucleus at the center of a ring galaxy. Seyfert galaxies are examples of such active conglomerates of stars and are believed to be an intermediate state between ordinary galaxies and quasars.



A cosmic collision between two galaxies formed this rare ring galaxy (upper right). The ring is 100,000 light-years across and one billion light-years from Earth. The ring was made when a disk galaxy was pierced by an "intruder galaxy", whose remains are probably the cigar shaped galaxy at lower left. Further study will reveal whether or not the other two galaxies are related. Kitt Peak National Observatory photograph.

BRIEFS

● Two NASA Landsat spacecraft may be used to assist in the 1980 census. Tests are being made as part of a joint project being initiated by the Bureau of the Census and NASA.

● NASA's Marshall Space Flight Center has developed a solar simulator which will provide imitation sunshine — day or night — for testing solar energy collectors.

● NASA is working with the Agency for International Development (AID) in a project to demonstrate the capabilities of Applications Technology Satellite-6, to bring space age technology to developing countries in southeast Asia, the Middle East, Africa and South America.

● The Boeing Aerospace Company was selected by NASA and the Energy Research and Development Administration for negotiations that will lead to the award of a contract to study space based solar power concepts.

The study calls for specific details on data necessary for the most effective means of accomplishing solar energy-to-electrical energy conversion on a solar power satellite system, and determination of the location in space for its construction and assembly.

● Comstar D-2, the second in a series of Comsat domestic communications satellites, was launched last summer from Kennedy Space Center. It will be part of a nationwide communications network capable of providing reliable communications to the 48 contiguous states, Alaska, Hawaii and Puerto Rico.

● Robots and their potential impacts on society will be studied by EIKONIX Corporation under a grant from the National Science Foundation's Research Applied to National Needs program.

The purpose of the study is to identify, in advance, major effects and different ways to use robots in aspects of society such as industry, labor, international trade and everyday life. The study will use data on current and projected robot technology to examine a wide range of effects of different ways that robots can be used.

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Scientists Use Expansion Rate to Determine Age of the Universe

Allan Sandage and G.A. Tammann of Hale Observatories have been attempting to define the rate of expansion (and hence the age) of the universe for many years. Their work has mainly involved finding and applying methods of determining the true distances to a reliable sample of galaxies whose redshifts are known. Once both distances and redshifts are known, the age of the universe — the length of time necessary for galaxies to reach their present positions — can easily be calculated.

The difficulty lies in the many steps necessary to determine the true distance of distant galaxies. Starting from celestial mechanics and radar measurements inside our own solar system, distances to nearby stars are based on measurement of parallax, to distant stars on spectroscopic calibration via nearby stars, to clusters through Cepheid variables and the fitting of their main sequences, to nearby galaxies through calibrations of the bright stars and clusters, and to more distant groups of galaxies through calibrating the characteristics of nearby galaxies.

In any long chain of calibrations, small inaccuracies build up into vast uncertainties. Sandage and Tammann have sytematically reviewed the distance calibration process in light of a new method involving the width of the 21cm line of hydrogen: the brighter the galaxy, the greater the width of its 21cm line. By calibrating the galaxies of the Virgo cluster against nearby spirals using the 21cm line method and combining this value with the best results from six other methods, the distance to the Virgo cluster galaxies was found more accurately than ever before.

The value obtained for the Hubble constant is 50.3km/second /megaparsecs, with an uncertainty of about 10 percent. The age of the universe obtained from this rate of expansion is 19.6 billion years, with an uncertainty of 1.6 billion years either way.

Sandage and Tammann have gone on to show that a universe of this age cannot collapse back upon itself, but must continue to expand forever.

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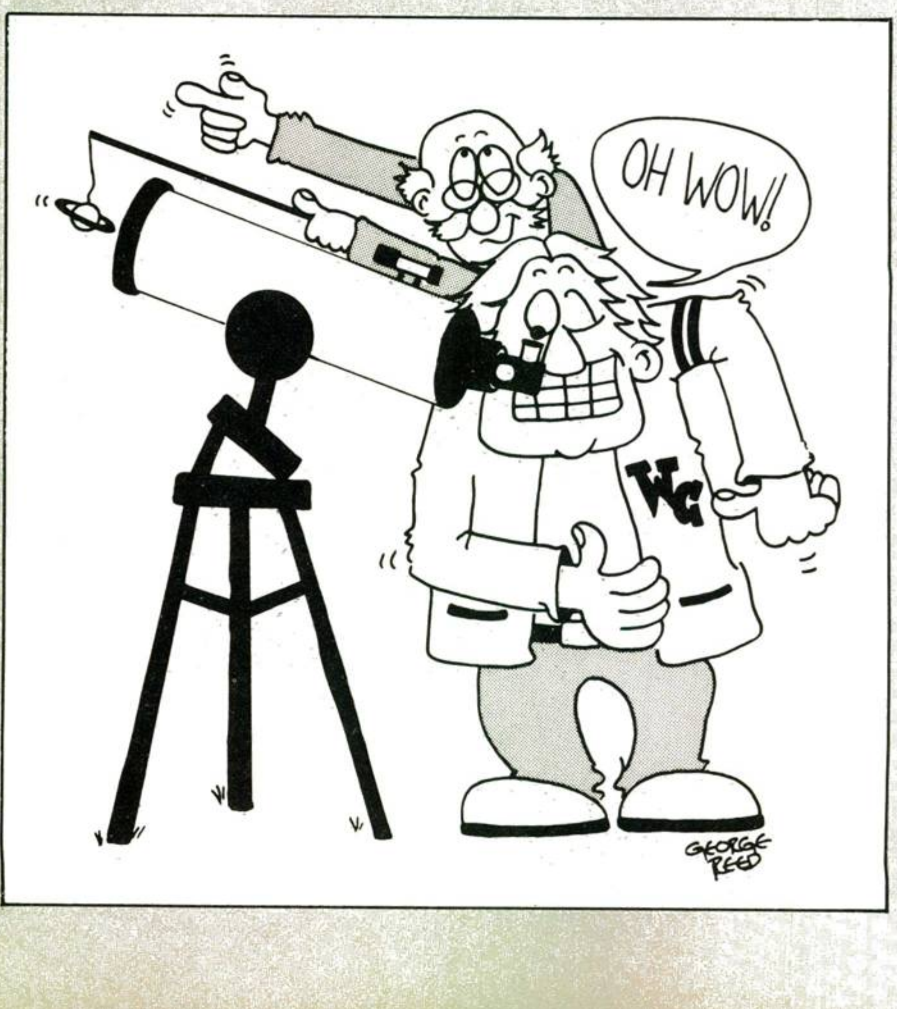

Starscapes

Topics in Astronomy

Gerrit L. Verschuur
University of Colorado, Boulder

STARSCAPES brings together twenty-seven brief essays, all written by Dr. Gerrit L. Verschuur, Director of the Fiske Planetarium in Boulder, Colorado. Copiously illustrated and informally written, these essays range over a number of topics of high interest now to both students and lay readers; among them: steller evolution, life in space, interstellar communications, exploding galaxies, black holes, and relativity. Dr. Verschuur is adept at succinctly providing all the background information needed for an understanding of each particular topic, then building on this background to discuss recent discoveries and their implications. Both scientifically accurate and accessible to the non-specialist, STARSCAPES will make an excellent supplement to an introductory text, adding or expanding coverage of topics students find most interesting. It can be used equally well as a core text for a topical course in astronomy, or as an overview of current topics for the interested amateur.

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California Institute of Technology

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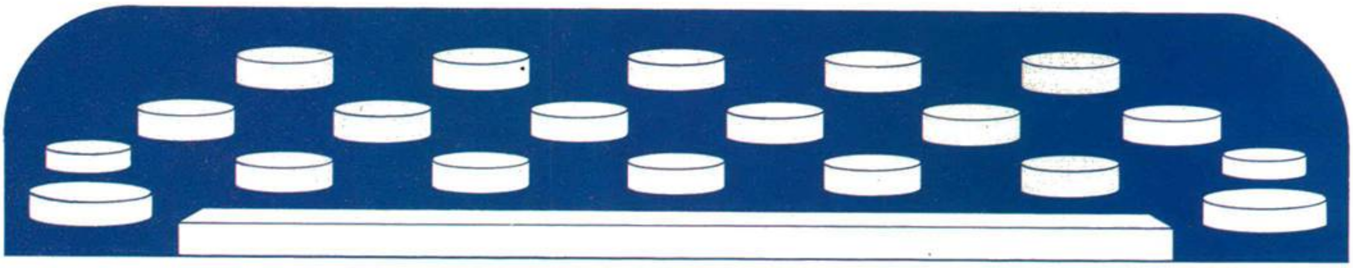

IN FOCUS

Sir / In your October 1975 issue you ran an article about Alpha Orionis (Betelgeuse) being photographed with the aid of an image intensifier and a computer television system. You haven't printed anything regarding image intensifiers since then, so I was wondering if you intend to do so.

WILLIAM KUEHLER
Glen Riddle, Pa.

Mr. Kuehler / Image intensifiers are widely used by professional astronomers today for research photographs. However, the images obtained often have defects, blotches, and other false markings that make the pictures rather ugly. Although image intensifiers will compete with direct photography someday, at present they do not have the beauty of direct photography.

We will, however, soon bring you exciting new results from computer processed astrophotography. Also, keep an eye on Equipment Atlas. Image intensifiers now available to the astronomy enthusiast can brighten your view through the eyepiece!

Sir / In the article on the Messier Catalog in the December 1976 issue of ASTRONOMY, it is stated that M-1 (the Crab nebula) contains the first discovered pulsar. To the contrary, there were more than 20 known pulsars at the time of the discovery of the Crab pulsar (NP-0532).

The Crab pulsar has the shortest period and largest relative period increase of presently known pulsars. The Crab pulsar's period is too short for a white dwarf pulsation period, and one expects the period of a rotating neutron star to increase while it is difficult to see why the period of a pulsating white dwarf would increase. If the Crab pulsar had been the first discovered, presumably the question of whether pulsars were pulsating white dwarfs or rotating neutron stars would not have arisen.

J.W. KNIGHT III
INSTITUE FOR PLASMA
RESEARCH
Stanford, Calif.

Sir / In the December 1976 issue of ASTRONOMY, I noticed that your Sky Almanac writer wrote a confused explanation for Vesta's appearance at opposition in January. The definitions for aphelion and perihelion are interchanged, and incorrectly applied.

I especially like Astro-News and your articles on astrophotography.

GEORGE H. AYERS
Associate Professor of Physical Science
University of Maine at
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Mr. Ayers / Thanks for keeping us on our toes.

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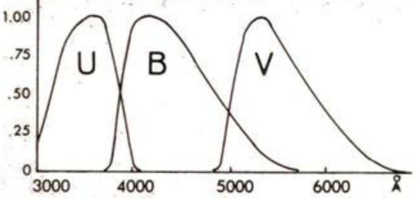

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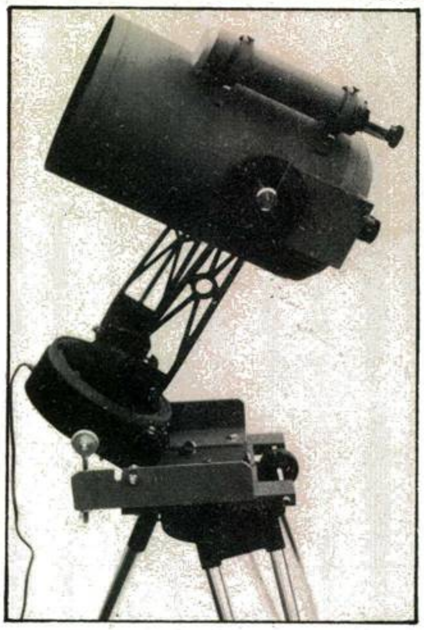

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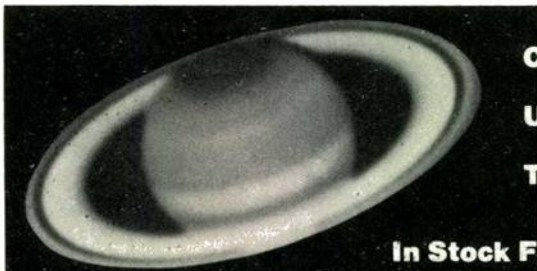

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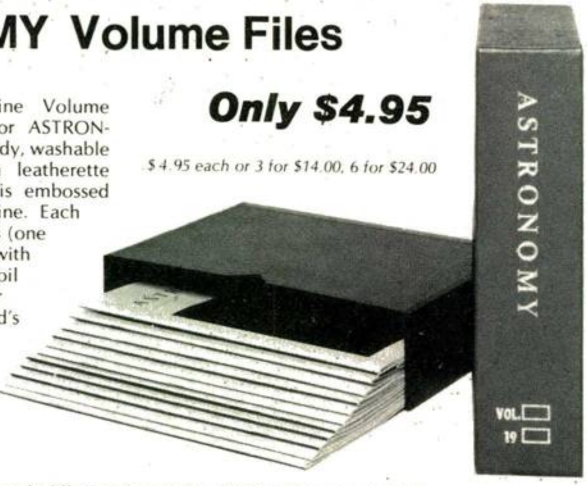

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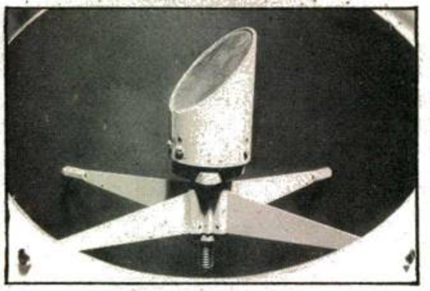

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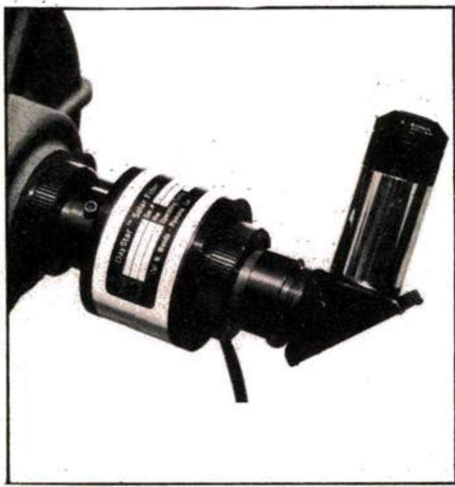

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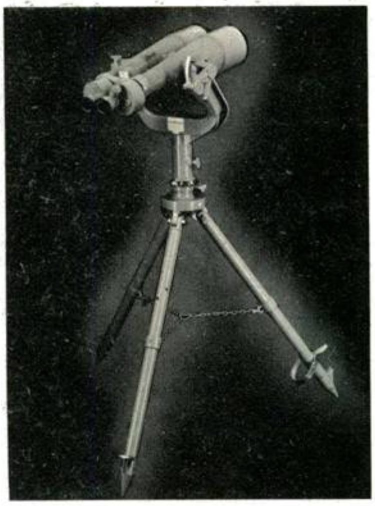

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ANNOUNCEMENT — The H.H. Astronomical Association is holding an astronomy fair for papers, photos. Open to any high school or college student. For competition details, write P.O. Box 492, Hibbing, MN 55746.

ANNOUNCEMENT — National Amateur Astronomers' Convention will be held Aug. 10-13, 1977 at University of Colorado in Boulder, with participation of AL, ALPO, IOTA, WAA. For information, write Denise Nye, NAA Convention Registration, 5604 Bowron Pl., Longmont, CO 80501.

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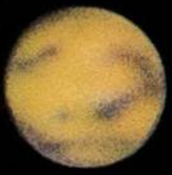
Planet Finder

Ⓒ Ceres

March	1	15
R.A.	12h56m	12h47m
Dec.	+11°36'	+13°03'
Mag.	+7.2	+7.1



Ⓐ Mercury

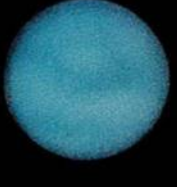
March	1
R.A.	22h09m
Dec.	-13°41'
Mag.	-0.6

Ⓑ Mercury

March	15
R.A.	23h44m
Dec.	-3°20'
Mag.	-1.4

Ⓜ Mars

March	1	15
R.A.	21h14m	21h57m
Dec.	-17°06'	-13°39'
Mag.	+1.4	+1.4



Ⓝ Neptune

March	15
R.A.	17h00m
Dec.	-21°13'
Mag.	+7.7

SUN

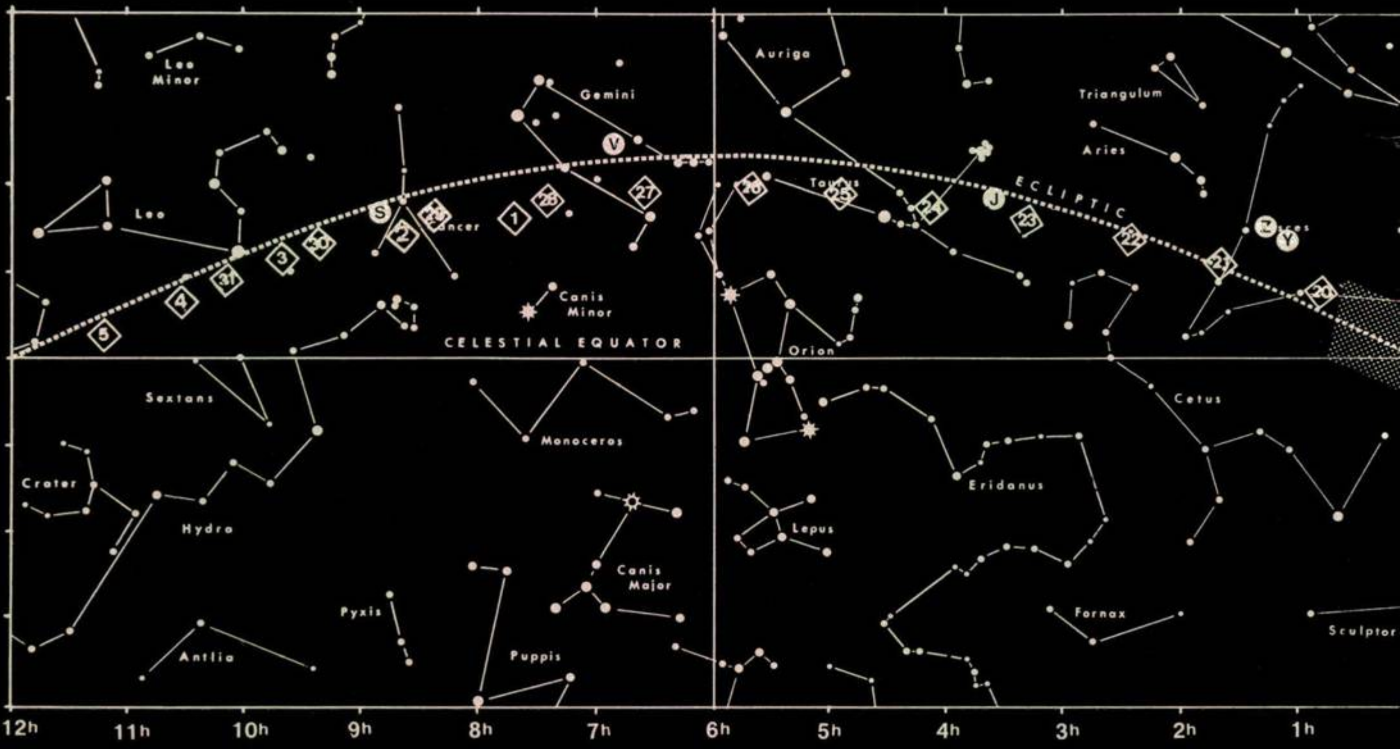
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

March	1	15
R.A.	8h56m	8h53m
Dec.	+18°19'	+18°32'
Mag.	+0.2	+0.2

Ⓤ Uranus

March	15
R.A.	14h36m
Dec.	-14°49'
Mag.	+5.7

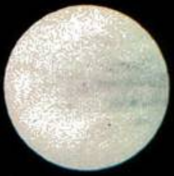

Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
Cancer
Taurus
ECLIPTIC
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Monoceros
Cetus
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Antlia
Puppis
Sculptor
V
S
J
Z
Y
1
2
3
4
5
20
21
22
23
24
25
26
27
28
29
30
31
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

March 1977

Ⓥ Vesta

March	1	15
R.A.	6h46m	6h50m
Dec.	+25°52'	+26°03'
Mag.	+7.5	+7.7



Ⓙ Jupiter

March	1	15
R.A.	3h29m	3h37m
Dec.	+18°11'	+18°44'
Mag.	-1.8	-1.7

Ⓨ Venus

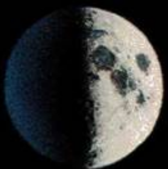
March	1
R.A.	1h09m
Dec.	+12°53'
Mag.	-4.3

Ⓩ Venus

March	15
R.A.	1h20m
Dec.	+16°07'
Mag.	-4.2

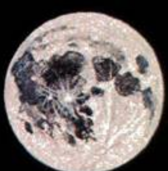
Ⓟ Pluto

March	15
R.A.	13h15m
Dec.	+11°03'
Mag.	+14



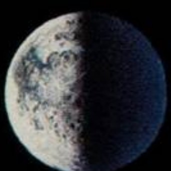
First Quarter

March 27



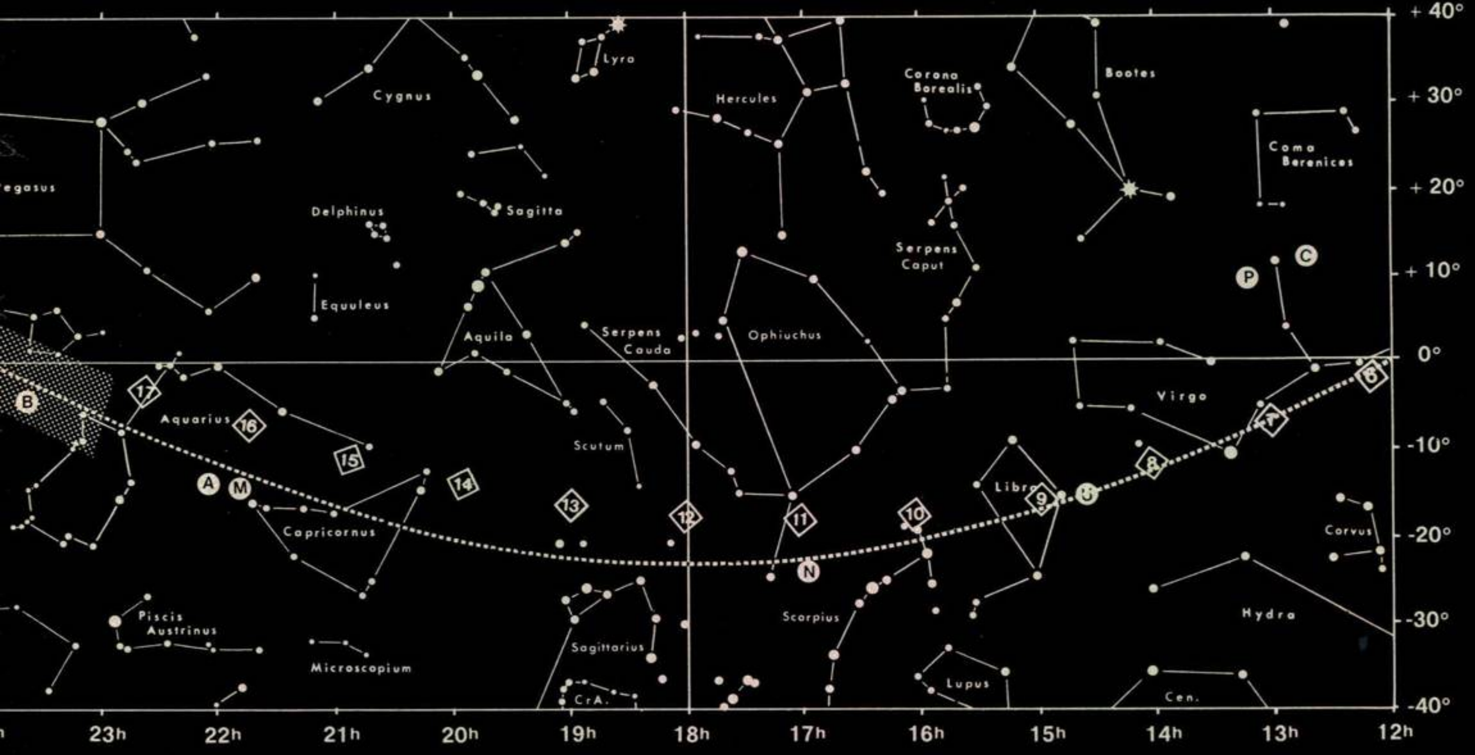
Full Moon

March 5

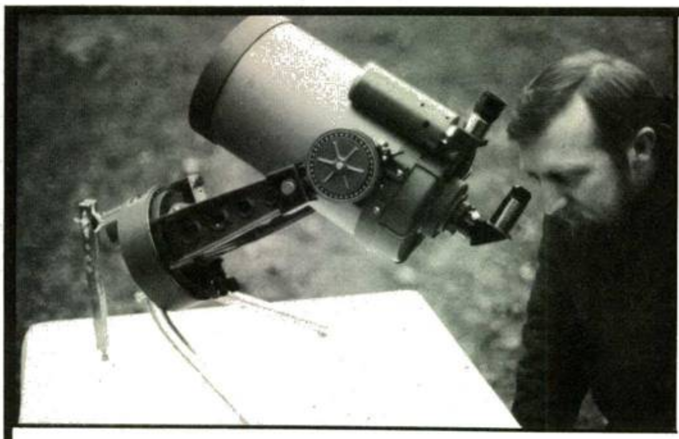


Last Quarter

March 12


egasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
P
C
B
Aquarius
17
16
15
14
13
12
11
10
9
8
7
6
A
M
Scutum
Libra
Virgo
Corvus
Capricornus
N
Scorpius
Hydra
Piscis Austrinus
Microscopium
Sagittarius
Lupus
CrA.
Cen.
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
h
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.



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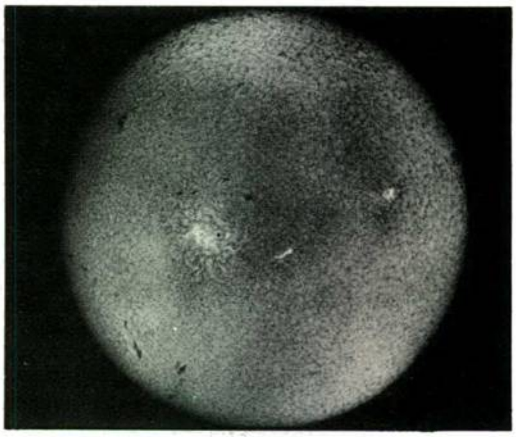

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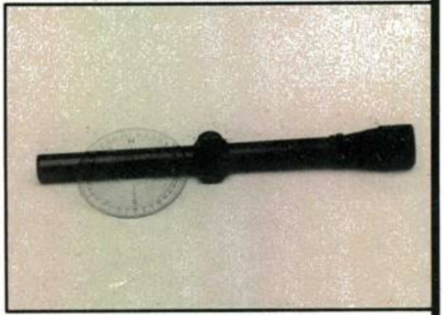

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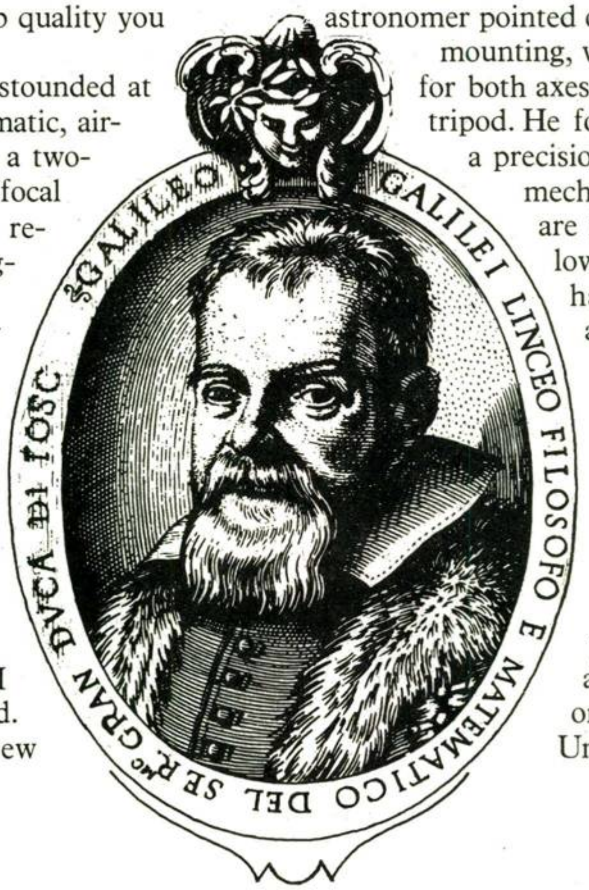
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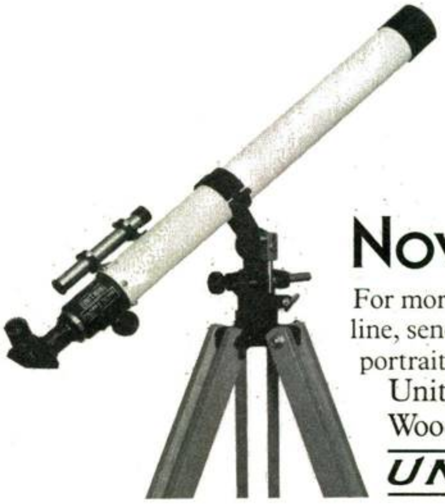

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STAR DOME

MARCH

by
James Mullaney & Henry J. Phillips

As the winter Milky Way silently passes its zenith and the bright constellations along it begin to slip down toward the western horizon, the dimmer star patterns of spring rise to announce the return of milder weather and the reawakening of life from hibernation. Stargazers await the annual return of Leo with as much anticipation as nature lovers watching for the first robin or crocus. Unlike the icy, hard brilliance of the winter constellations, or the summer groups' distant sublimity, the stars of spring seem to bring a warm friendliness to March nights.

Observers in midnorthern latitudes take the comparative dimness of the spring constellations for granted. Farther south, however, this is not the case. The Milky Way, so faint and featureless in the winter sky, broadens and brightens considerably south of Canis Major, and southern stargazers at this time have an excellent view of one of the most magnificent portions of the entire sky. Set upon this beautiful section of the Milky Way is the great ship Argo, of which observers in the north can see no more than a bit of the stern, just east of Canis Major. This is unfortunate, for Argo contains Canopus, the second brightest star in the sky — as well as eight second magnitude stars, and innumerable clusters and nebulae.

Actually, Argo is made up of three distinct constellations: Carina, Vela and Puppis. Argo had to be split into these subdivisions during the 19th century, when its huge size made the lettering and numbering of its many stars difficult. The constellation boundaries instituted in 1930 by the International Astronomical Union made these divisions official and permanent. Carina represents the ship's keel, with Puppis standing for the stern and Vela the sails, so we are free to continue seeing a ship in this massive collection of stars, as the ancients did.

Of all the Greek myths, that in which the ship Argo figures is probably the least edifying; virtually all the characters are scheming and unscrupulous, and the golden fleece that serves as the impetus for all the action is hardly more than an excuse for the extensive bloodletting that occurs in this story. The fleece was worn by an intelligent, speaking ram (represented in our skies by the constellation Aries) that was sent by Zeus to save Phrixus and Helle — two children who were in danger of death at the hands of their evil stepmother, Ino. The children were the heirs to the throne of Boeotia, which Ino wanted for herself. The ram picked up the children and flew away with them to the kingdom of Colchis. Unfortunately, Helle lost her hold on the way and fell to her death, but Phrixus hung on and touched down safely in Colchis. He proceeded to show his gratitude to the ram by sacrificing it! The ram's fleece fell into the hands of Colchis' king, Aeëtes, and matters remained at a standstill for several years.

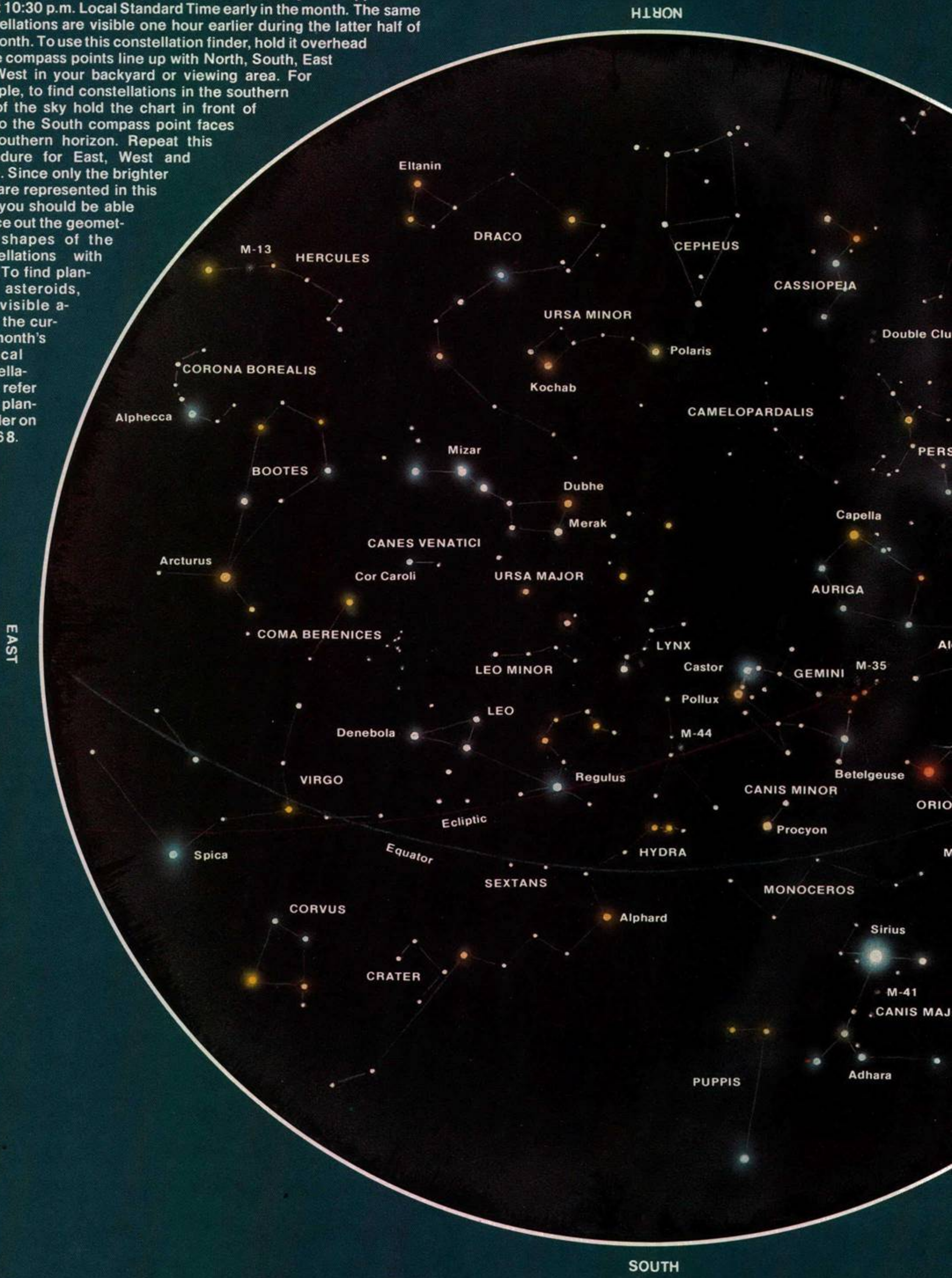
At this point, in the kingdom of Iolcus in Greece, King Aeson was ousted by his brother Pelias. Wishing to rid himself of Jason, the king's son, Pelias offered Jason a share in the throne in return for the golden fleece, which Jason immediately set forth to fetch. Neither Pelias nor Jason appear to have had any second thoughts about wresting the fleece from its owners — a bit of perfidious behavior that is typical of this myth.

With the aid of the goddess Hera, Jason built the ship Argo, and gathered every major hero in Greece to share in his quest. The crew (known as the Argonauts) sailed to Colchis, undergoing a series of adventures on the way, in most of which theft and dishonesty figure prominently.

When confronted by this mob of armed rowdies demanding the golden fleece, King Aeëtes promised it to them on the condition that Jason proved able to perform a series of nearly impossible tasks. One of these involved yoking two mad bulls to a plow, sowing the ground with dragon's teeth, and then singlehandedly fending off the resultant crop of armed men! But Aeëtes' daughter Medea — who was extremely beautiful, and a sorceress besides — fell so madly in love with Jason that she aided him with her magic arts, and Jason accomplished all the tasks set before him.

As might be expected, Aeëtes refused to give away the fleece as he had promised, so Jason and Medea simply stole it from under the nose of the dragon that guarded it. Together with Medea's brother, the two then hastily left Colchis with the Argonauts. Aeëtes gave chase in his own ships, whereupon Medea coolly dismembered her own brother and tossed the pieces into the sea. Aeëtes stopped to collect the fragments, and the Argo escaped. After returning to Iolcus, Medea rid the kingdom of Pelias by inducing his daughters to murder him under the pretense that they were magically

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 68.


NORTH
Eltanin
DRACO
CEPHEUS
M-13
HERCULES
CASSIOPEIA
URSA MINOR
Double Clu
Polaris
CORONA BOREALIS
Kochab
Alphecca
CAMELOPARDALIS
Mizar
PERS
BOOTES
Dubhe
Capella
Merak
CANES VENATICI
Arcturus
Cor Caroli
URSA MAJOR
AURIGA
EAST
COMA BERENICES
LYNX
Al
Castor
M-35
LEO MINOR
GEMINI
Pollux
LEO
Denebola
M-44
Regulus
Betelgeuse
VIRGO
CANIS MINOR
ORIO
Ecliptic
Procyon
Spica
Equator
HYDRA
M
SEXTANS
MONOCEROS
CORVUS
Alphard
Sirius
CRATER
M-41
CANIS MAJ
Adhara
PUPPIS
SOUTH

Map Centered on 40° North Latitude

ANDROMEDA
TRIANGULUM
Algol
ARIES
Pleiades
CETUS
Hyades
TAURUS
WEST
Bellatrix
ERIDANUS
Rigel
LEPUS
COLUMBA

Map by Adolf Schaller

restoring him to youth. Jason and Medea had to escape to Corinth for protection, where they married, had two sons, and lived in peace for years.

But two such unsavory characters as Jason and Medea could not live together happily forever. After 10 years, Jason tired of his wife and decided to marry Creusa, the daughter of the Corinthian king — who, wishing for Creusa's peaceful wedded bliss, proclaimed exile for Medea. Pretending resignation to her fate, Medea sent the bride a wedding gift — a lovely gown that she had specially prepared. Creusa, donning the beautiful gift, was consumed by flame. In a blind fury, Jason stormed to Medea, only to find his two sons murdered by their mother, and Medea fleeing Corinth in a chariot drawn by dragons. Years later, Jason himself was killed as, recalling past glories, he sat in the shade of the now-rotting Argo; the timbers of the stern gave way and Jason was crushed to death.

It is noteworthy that no god or goddess (with the exception of Hera, who always loved a good ruckus) takes any direct part in this horrible story, almost as if they were averting their eyes. The vile and treacherous deeds of everyone involved make this a most unusual Greek myth (most of them contain at least one redeeming character), and it is therefore an interesting one. The story's origins are lost; the quest of the golden fleece became the subject of a long poem by the Roman writer Appolonius of Rhodes, while the playwright Euripides told the rest of the story in his **Medea**. The ship Argo was immortalized in the stars in preference to any of the major characters; one is tempted to add, "and rightly so!"

During the Middle Ages, Argo was rechristened Noah's Ark (a natural outcome). By that time, however, the precession of the equinoxes had carried the ship down closer to the south celestial pole, and over the centuries it slowly disappeared from sight in the northern hemisphere — almost as if it were sinking. Today, as mentioned above, Argo is well-situated for observing only in the extreme southern United States, or from areas farther south.

Subdivided as it is today, Argo can no longer lay claim to the title of the largest constellation. That honor instead goes to Hydra, visible this month south of Leo. Covering a total area of 1,303 square degrees, Hydra is an extremely long, thin constellation, stretching across seven hours of right ascension. For all this great size, Hydra has very little to show, containing only one star brighter than third magnitude. This star is named Alphard, from the Arabian title Al Fard al Shuja, the solitary one in the serpent — a name befitting Alphard's isolated position in the sky. Alphard's magnitude is 1.98; it lies about 94 light-years away, and it is an orange giant, similar to Arcturus.

Such an elongated constellation as Hydra could hardly escape being known as a serpent of some sort, and so it has been to most nations. A matter of more conjecture has been exactly what kind of serpent Hydra represents. Today it's generally referred to as a sea serpent, but this is not a title that existed before the 17th century or thereabouts. Earlier, Hydra stood for a dragon, an asp or a viper to various nations. In Chaldea, Hydra was one of several star groups that represented the dragon Tiamat — a personification of the blind forces of chaos, against which the gods and all they created constantly struggled. The Egyptians, however, called Hydra the River Nile.

Hydra's head, situated just south of the zodiacal constellation Cancer, is an attractive group of stars, well suited for observation with binoculars or an RFT. East of the head, between Hydra and Leo, is Sextans the sextant, one of the constellations originated by the astronomer Hevelius that we discussed here last month. Hevelius' original title was Sextans Uraniae, the sextant of the heavens; Hevelius was the last proponent of the virtues of the sextant over those of the telescope for measuring star positions, and he put Sextans in the sky to commemorate the one he had used for many years. The constellation is a dim one, containing only one star as bright as fourth magnitude.

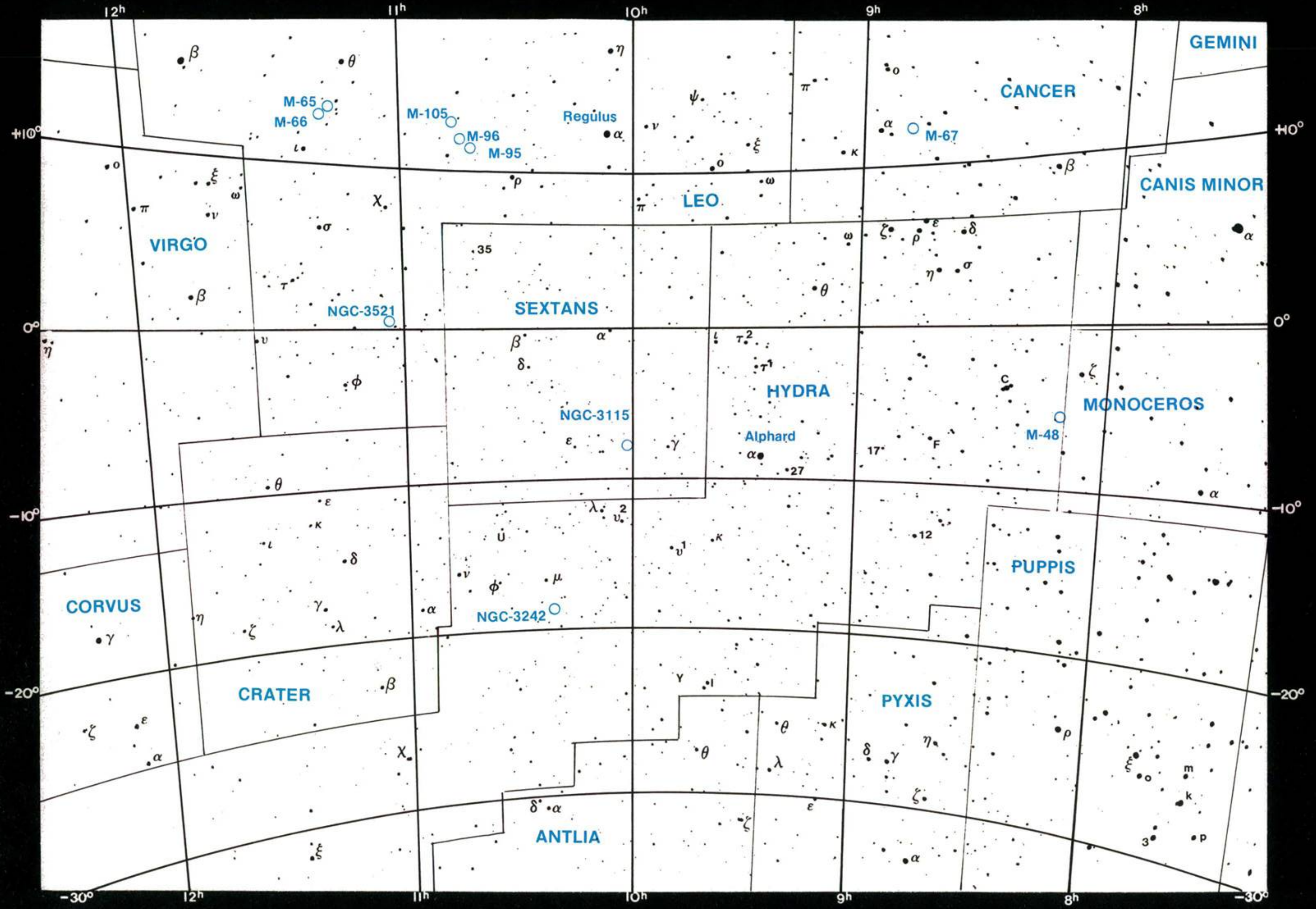
Close-Up

Western Hydra/Sextans Region

Hydra is not only the largest constellation, but by far the longest. It extends from 8 hours to 15 hours of right ascension — bordering both Canis Minor in the winter sky and Libra in the summer heavens!

Barns wrote: "The limited pentagonal area [of Hydra's head]. . . is quite the most compelling section of the mythical monster which drags its dull length from this point south and eastward nearly a third the distance around the celestial sphere. It would be strange indeed if so vast a precinct were not relieved here and there with some veritable highlights, available in our latitudes with fine seeing."

For its extensive size, the water monster is poorly stocked with subjects and is also one of the most obscure celestial figures. This month's survey includes the area of sky from Hydra's


GEMINI
CANCER
CANIS MINOR
LEO
Regulus
VIRGO
SEXTANS
HYDRA
Alphard
MONOCEROS
PUPPIS
PYXIS
ANTLIA
CRATER
CORVUS
M-65
M-66
M-105
M-96
M-95
M-67
M-48
NGC-3521
NGC-3115
NGC-3242
12h
11h
10h
9h
8h
+10°
0°
−10°
−20°
−30°

Photograph by Brad Wallis and Robert Provin
Map by Richard Berry

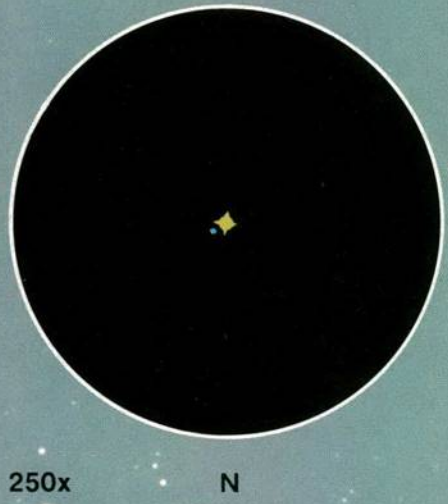
head as far east and south as the border of Crater.

To the unaided eye, Hydra's most prominent feature is its rhomboidal-shaped head. Olcott referred to this figure as a "striking and beautiful group of stars". Barns elaborated on the scene: "Zeta, Epsilon, Rho, Delta, Sigma and Eta Hydrae, in same field, with lesser lights, presents a brilliant pageant." A look here with wide-angle binoculars will quickly show what all the talk is about. Another naked eye highlight of Hydra is Alphard [Alpha (α) Hydrae], southeast of the head. This second magnitude reddish-orange star marks the heart of the creature.

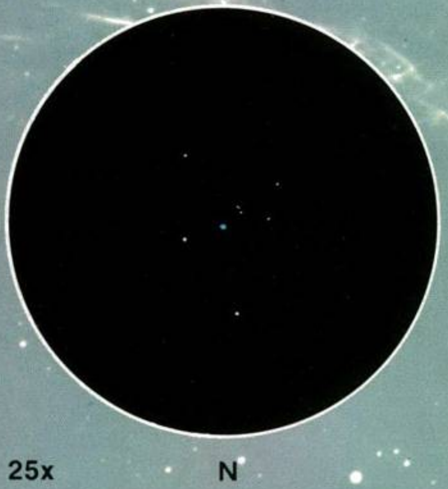
This month's region also includes an adjoining and equally obscure constellation — Sextans, the sextant. Webb introduced it this way: "A modern asterism, as its name denotes, being one of the minor constellations, formed by Hevelius out of unclaimed stars lying between the ancient ones." The sextant sits directly on the coiled back of the monster, just east of its head and directly under Regulus in Leo. It contains no star brighter than fourth magnitude, and was called a "little asterism" by Olcott.

Despite the barren aspect of this month's region, it does contain some telescopic sights, to which we now turn our attention.

Epsilon Hydrae



NGC-3242



Epsilon Hydrae is a lovely yellow/blue color-contrasting double star. The two components lie only three seconds of arc apart, and fairly large telescopes must be used to bring out the colors well. This view is through an eight inch reflector at 250 power; the field of view is about 10 minutes of arc. NGC-3242 is a large, distinctly blue, planetary nebula, easily visible through a 2.4 inch refractor (as this drawing shows). Several background stars are also included. Magnification is 25 power; the field of view is about two degrees. Drawings by James Mullaney.

Selected Objects — Western Hydra/Sextans Region

Object	Type	Mag.	Size/ Sep.	R.A.(1950)	Dec.
HYDRA					
* M-48	OC	5.3	30'	$8^{h}\ 11^{m}$	-05°38'
* ϵ (Epsilon)	⋆2	3.5,6.9	3"	$8^{h}\ 44^{m}$	+06°36'
17 Hydrae	⋆2	6.7,6.9	4"	$8^{h}\ 53^{m}$	-07°47'
27 Hydrae	⋆3	5.0,6.9,9.0	229",10"	$9^{h}\ 18^{m}$	-09°21'
I Hydrae	⋆2	4.8,8.1	54"	$9^{h}\ 39^{m}$	-23°22'
* Y Hydrae	V:303^{d}	6.9-7.9	—	$9^{h}\ 49^{m}$	-22°47'
* NGC-3242	PN	9	40"x35"	$10^{h}22^{m}$	-18°23'
* U Hydrae	V:Irr	4.8-5.8	—	$10^{h}35^{m}$	-13°07'
SEXTANS					
* NGC-3115	El	9.3	4'x1'	$10^{h}03^{m}$	-07°28'
35 Sextantis	⋆2	6.3.7.4	6"	$10^{h}41^{m}$	+05°01'

* Detailed in Close-Up

⋆2 = Double Star
⋆3 = Triple Star
PN = Planetary Nebula
OC = Open Cluster
El = Elliptical Galaxy
V:#^{d} = Variable Star, period (days)
Irr = Irregular
Mag. = Magnitude
Sep. = Separation

Epsilon (ϵ) Hydrae

The star at the very top of Hydra's head, flanked by the stars Zeta (ζ) and Delta (δ), is a good starting point for our telescopic exploration of this region's wonders. This is the complex binary system, Epsilon Hydrae.

Here we encounter 3.5 and 6.9 magnitude suns, a tight three seconds of arc apart. A color contrast is evident; nearly all observers call the stars yellow and blue in tint. Smyth said they were pale yellow and purple, while Webb (in 1851) saw the companion as ruddy.

The two stars are in slow orbital motion about each other with an uncertain period given as 900 years. This motion has resulted in small but noticeable changes in the pair's separation and position angle over the years. In 1929, for example, these values were 3.6 seconds and 253 degrees, respectively. At present they are about 2.8 seconds and 280 degrees.

A three inch refractor at high power can resolve this duo on a steady night, but larger instruments are needed to really appreciate Epsilon's appeal. Our drawing, which shows the view through an eight inch reflector at 250 power, gives some idea of what is to be seen.

Good seeing (image steadiness) is extremely important in looking at Epsilon, which probably accounts for the pair having been missed by William Herschel during his long, intense sweeps of the heavens. His observing sites in England were frequently plagued by clouds and turbulent air — yet he pushed on to see and discover more than any observer who came before or after him! This should truly be a source of inspiration to all who love stargazing.

We have listed Epsilon Hydrae as a double star in our table, but it is actually at least a triple system. The primary has an extremely close fifth magnitude sun in rapid motion about it, discovered visually in 1888 by Schiaparelli. This companion never ventures wider than 0.3 seconds at greatest separation. It has also been picked up spectroscopically; in both cases, the orbital period is the same — 15 years. This is quite short for a visual pair, but extremely long for a spectroscopic one. The star thus presents a rare example of being both types of binary — a kind of borderline sun.

And we are not done yet, for there is a 12th magnitude star some 20 seconds distant that is drifting through space with the other members — an entire "clan waltzing" in the night!

Webb called Epsilon Hydrae "a

remarkable system". Modern determinations place its distance from us at 140 light-years.

M-48

At the extreme western boundary of Hydra resides a cosmic personality that was considered "lost" for years, but turned up "alive and well" a few years ago. This is the open cluster M-48, located about three degrees southeast of fourth magnitude Zeta Monocerotis.

For years this object was regarded as one of the missing entries in the Messier catalog, but it has now been convincingly identified as NGC-2548 by Harvard astronomer/historian Owen Gingerich. The cluster's right ascension is essentially that given by Messier, but its declination is exactly five degrees south of his value. Messier apparently made an error in recording his discovery position.

M-48 is just visible to the unaided eye on a dark transparent night, but it's not easy to locate with the telescope due to the lack of any nearby guide stars. However, careful sweeping with your finder will pick it up.

This cluster contains some 80 stars in an area the size of the full moon (30 minutes), and together these shine with the luster of a 5.3 magnitude star. It is fairly rich for an open cluster, and a fine sight in four to eight inch scopes at low power.

Webb listed this object under neighboring Monoceros as NGC-2548, describing it as a "group of pretty uniform ninth magnitude stars, with a profusion of lesser ones." Holyoke — a modern observer — tells us that M-48 is ". . . a fine galactic cluster well worth having back in the catalog and observing."

This "misplaced" swarm of suns glistens at us from across 3,500 light-years of interstellar space.

U and Y Hydrae

We come now to two vivid red variable stars well worth a look by those who enjoy celestial colors. The first of these is U Hydrae, which forms the top of an equilateral triangle with third magnitude Nu (ν) and fourth magnitude Mu (μ) in the body of the monster. This star is an irregular variable of uncertain period, and ranges from 4.8 to 5.8 magnitude — easily within reach of finders and binoculars.

The other red cosmic eye is designated Y Hydrae. It can be found two degrees east and slightly north of the fourth magnitude double star I Hydrae (see our table of selected objects). This pulsating sun is classified as semiregular and has a period of 303 days. Like U Hydrae, it varies by a full magnitude — this time from 6.9 to 7.9.

Both of these objects are of the rare spectral class N and through the telescope have a striking deep red cast. Although listed without comment or omitted entirely from most observing references, they present stunning sights, especially on dark nights.

Deeply tinted orange and red stars are missing from the observing diet of most deep sky watchers today, but back in Webb's time they received special attention. Indeed, observers like Espin and Birmingham in England conducted extensive surveys of the sky looking for just such objects!

Most of these celestial stoplights are long period variable stars; in selecting them as telescopic showpieces for visitors, it is important to find ones with fairly limited magnitude ranges. You'll want to make sure they'll be visible when you show them to others, as many vivid red stars will drop below your scope's limit at the minimum phase of their light cycles.

NGC-3242

Just two degrees south of fourth magnitude Mu Hydrae lurks one of the most vivid and remarkable planetary nebulae in the heavens. This is NGC-3242, sometimes referred to as the "Ghost of Jupiter".

This neglected showpiece was highlighted as part of the Corvus-Crater region in the May (1975) Star Dome. Readers should check that issue for a detailed description and color sketch of this unusual object.

NGC-3242 is an exciting sight and is worth checking on whenever you happen to be in this part of the sky. Aside from its surprising size, eerie blue light and the complex structure within its disk, variations of its nucleus have been reported in the past by visual observers like Pickering. These may occur again in the future — or, indeed, be underway right now!

In our revisit to NGC-3242, we hope to dispel somewhat of a myth — that, as a class, planetary nebulae are difficult to observe and cannot be seen unless a fairly large scope is used. True, these objects are generally much smaller in apparent size than other types of deep sky objects, but many of them can be seen in the smallest of telescopes and at very low powers. Our drawing of NGC-3242 as seen through a 2.4 inch refractor is such a case. A magnification of just 25 times clearly shows the characteristic nonstellar appearance of the planetary — in this instance blue in color, but more usually green or blue-green. Even if you own a larger telescope, it's fun to see just how low a power will still distinguish the nebula from the surrounding stars.

Dozens of these strange and intriguing objects can be picked up in a small instrument by a trained and patient eye. Larger telescopes, such as a six or eight inch, will reveal each of these to have a "personality" all its own — no two are exactly alike! Surprises abound here as in other fields of observing. A little-known object like NGC-3242 will often rival a superstar like M-57 (the Ring nebula), and yet will rarely be paid a visit by astronomy enthusiasts. No wonder some observers claim these rejects of cosmic society as all their own!

At a distance of some 2,000 light-years, the Ghost of Jupiter lies 3,000 light-years nearer to us than the Ring nebula.

NGC-3115

We close our survey of this month's sparse region with a final stop at a remote extragalactic outpost in Sextans. This is the elliptical galaxy NGC-3115, situated seven degrees south of fourth magnitude Alpha Sextantis and three degrees east of fifth magnitude Gamma (γ). Finders often fail to show this deep space object; it's best swept up by scanning its position with the telescope itself.

Egg shaped NGC-3115 measures one by four minutes in size, and shines softly at 9.3 magnitude. It was discovered by Herschel and is the best of several galaxies lying within the confines of Sextans. There are very few published descriptions, indicating that little attention has been given this object and its host constellation. Webb, however, was not negligent here, for he described NGC-3115 as "Very distinct, with much brighter center, bearing magnifying unusually well". Barns also paid his respects, calling this object a "nebula" and mentioning a "glowing center".

Although this galaxy's outline can be seen in a three or four inch telescope on a good night even without averted vision, larger apertures show it to advantage. For the above descriptions, Webb used a 9.3 inch reflector, and Barns a 10 inch.

Despite the lack of attention NGC-3115 has received, it is well worth careful and thoughtful scrutiny with your telescope on a dark moonless night, especially when it's near the meridian.

Unlike other galaxies in crowded areas such as Coma Berenices or Virgo, NGC-3115's isolation seems complete. Undistracted, our minds are free to ponder the quiet scene set before us, and we can conjure up visions of a remote star city in the night. As James Elroy Flecker said: "What shall we tell you? Tales, marvelous tales of ships and stars . . . ." And, perhaps, life?

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